DISCOVERY

THE PROGRESS OF SCIENCE

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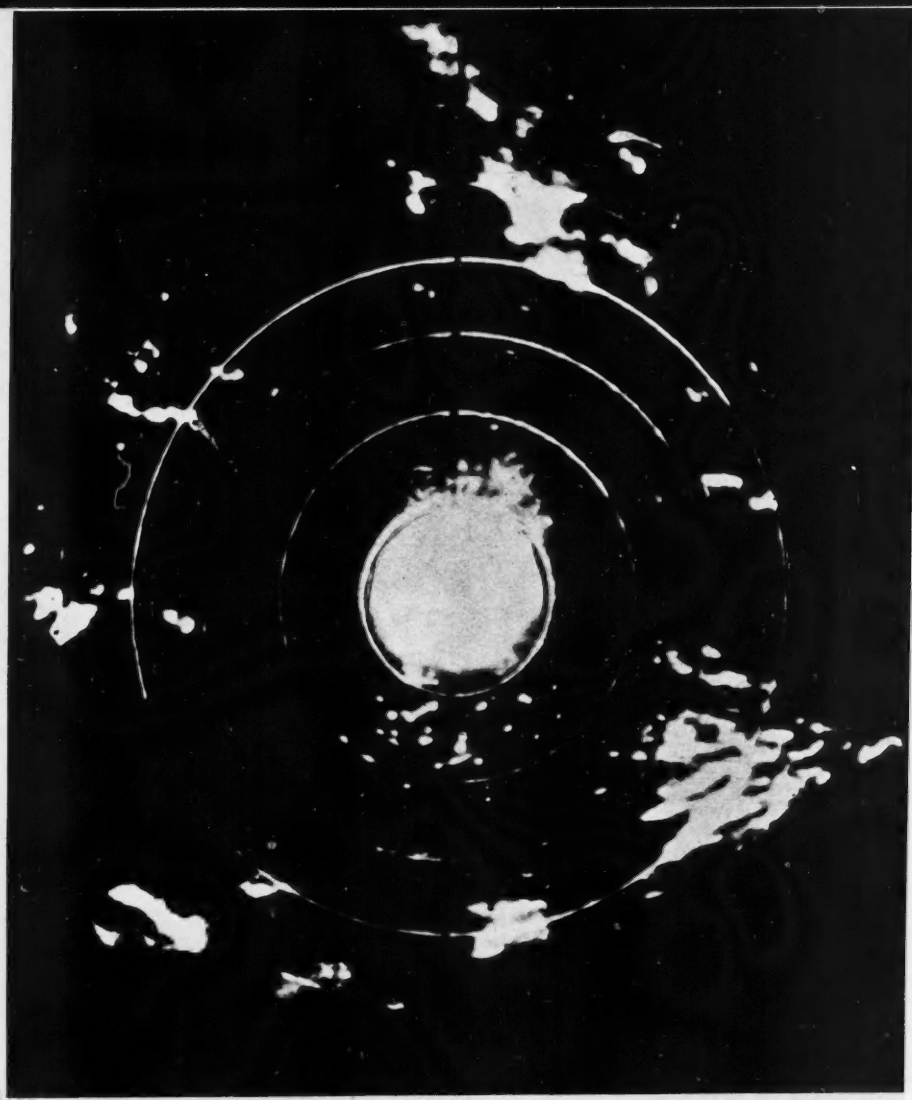

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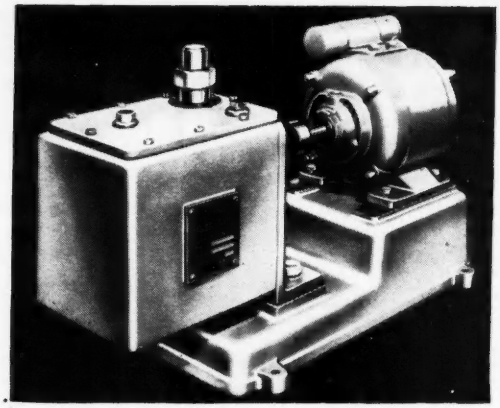

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

TOWARDS SELF-SUFFICIENCY IN SULPHUR

Nearly four years have passed since the 'sulphur crisis'. At that time, an embargo was placed on sulphur exports by the U.S.A. following the expansion in demand and reports of the impending exhaustion of the sulphur domes in Texas, exploited by the Frasch process to yield a cheap and very pure sulphur. It needed the intervention of the then Prime Minister, Mr. Attlee, with President Truman to obtain the release of 15,000 tons of sulphur to keep Britain's industry at work. A full control of sulphuric acid followed. (That story was told in DISCOVERY in 1951, in particular in 'Progress of Science' notes in February and March of that year.)

What was suggested in our columns for action to expand home production of sulphuric acid based on indigenous sulphur has now largely come to pass.

One way to meet the shortage was to make use of petroleum refinery gases containing hydrogen sulphide, and the second that we mentioned was expansion of the number of installations using the anhydrite process.

The Shell Petroleum Company has now announced that a second plant to produce 33,000 tons a year of sulphuric acid has begun operation. This makes use of hydrogen sulphide which arises from the processing of Middle East crude oil with its high sulphur content. In 1952, Shell built at Stanlow the first plant to recover elemental sulphur to the tune of 15,000 tons a year. The process gives a controlled oxidation of hydrogen sulphide according to the equation:

$$2H_2S + O_2 \rightarrow 2H_2O + 2S.$$

The sulphur so produced is highly pure and most useful for operations requiring sulphur in element form, such as rubber vulcanisation. The additional plant now uses some of this sulphur together with extra quantities of hydrogen sulphide arising from an expanded refining programme to burn completely to sulphur dioxide. This contains water which is produced by the following reaction:

$$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O.$$

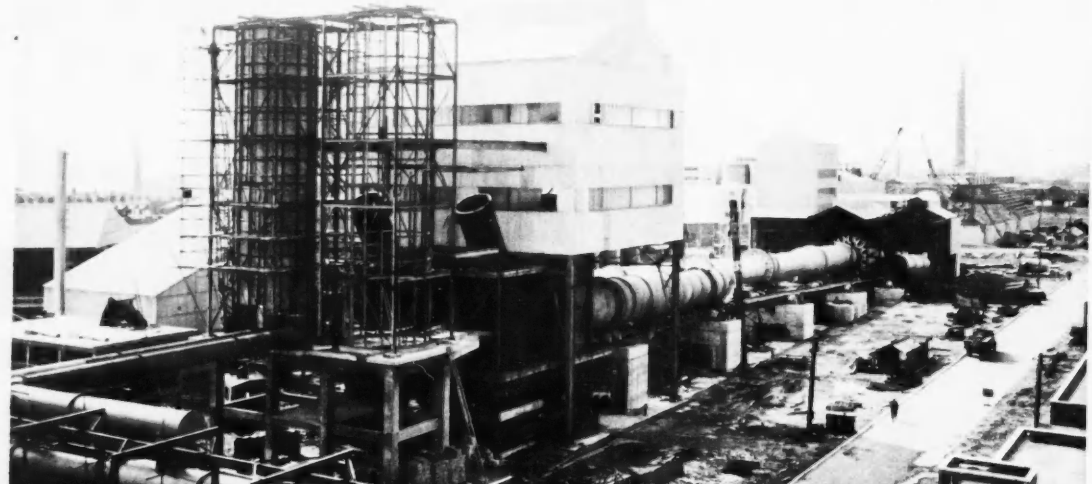
The sulphur dioxide is dried by passing the gas up towers which are filled with packing, over which trickles 93% sulphuric acid which absorbs the water. The dry sulphur dioxide is then converted to sulphur trioxide by passage over vanadium pentoxide catalyst and absorbed in sulphuric acid. The final products are 98% sulphuric acid and 20% oleum, which is sulphuric acid in which excess sulphur trioxide has been dissolved.

Anglo-Iranian's Grangemouth Refinery on the Firth of Forth is also contributing to our sulphur supplies, and is recovering 14 tons of this element a day.

A new factory producing sulphuric acid from anhydrite has been built at Widnes, and this is due to come into production this spring. It is owned by the United Sulphuric Acid Corporation, an organisation whose capital was guaranteed by twelve major firms that use sulphuric acid. Each firm's share of the factory's output of acid will be proportional to the capital it invested in the project.

This new factory will use about 240,000 tons of anhydrite (calcium sulphate) per annum, from which about 148,000 tons of sulphuric acid and 132,000 tons of cement clinker will be produced. This output of acid represents something like 7½% of Britain's present acid production and will save the import of 53,000 tons of sulphur costing about 2 million dollars a year.

The process consists in heating an accurately proportioned mixture of calcium sulphate with materials containing carbon, silica, alumina and ferric oxide, and the two resultant products are sulphur dioxide and cement clinker. The anhydrite comes from a quarry that has just been opened up in Cumberland. This raw material is delivered by rail. The anhydrite has to be crushed before it can be used.



Kilns for roasting anhydrite, with gas-coolers and mains to electrostatic gas cleaners in foreground.

The other materials—sand, shale and coke—are dried and then mixed in the correct blend with the anhydrite. The mixture is fed to rotary kilns, each 355 feet long, where pulverised coal is burnt to heat them. The silica, alumina and iron oxide in the sand, shale and coke combine with the lime in the anhydrite to form cement clinker, which is a combination of the alumino-ferrate and silicates of calcium. The clinker is cooled, crushed and then conveyed to an adjacent works to be processed into Portland cement.

The hot gases from the kiln are cleaned and cooled by scrubbing with water, passed through electrostatic precipitators to throw out droplets, and dried with sulphuric acid and so on to conversion as with refinery gases.

The completion of this new anhydrite plant comes at a time when the sulphur position is easier. New sulphur domes have been brought into production in the U.S.A. and Mexico. The long-term possibility of sulphur shortage remains, but by the expansion of sulphuric production from native anhydrite Britain's dependence on imported sulphur is minimised, which means dollar savings now and safety in the future should world demand tend to exceed world supply of this element.

Another anhydrite plant is under construction at Whitehaven in Cumberland. This has the advantage of being on top of anhydrite deposits, like the I.C.I. plant at Billingham, which has recently been expanded to produce 175,000 tons of sulphuric acid a year.

CLEAN AIR

The final report* of the Beaver Committee on Air Pollution strikes a crusading note. It regards air pollution as "a social and economic evil which should no longer be tolerated and that needs to be combated with the same conviction and energy as were applied one hundred years ago in securing pure water". The most serious immediate problem is seen to be visible pollution by smoke, grit and dust that are poured into the air by the nation's chimneys, and the committee sets as the target the reduction of this atmospheric pollution by 80% over the next ten to fifteen years in the most heavily populated districts. The chief polluters are domestic fires, factories and railways in that order; to take smoke alone, these produce 0·9, 0·8 and 0·3 million tons per year respectively. The effect of the smoke from household and locomotive chimneys is enhanced by the low level at which they discharge.

The nuisance arising from these sources is not easy to control under existing legislation. The Public Health Act 1936 contains no provision for the control of domestic smoke and there is no definition of 'black smoke' which allows easy proof, except where local authorities have made special bye-laws under one section of that Act. Smoke from railways is governed by two Acts; these provide that locomotives shall be constructed to consume their own smoke, and failure to do so is an

* Cmd. No. 9322, *Report of the Committee on Air Pollution* (H.M.S.O., 2*s*. 6*d*.).

offence, but as no particular body is responsible for enforcing these provisions, they seem to be disregarded.

The new report proposes a new 'Clean Air Act'. This would prohibit the emission of dark smoke, which is defined scientifically. The enforcement would be in the hands of the local authorities except for certain scheduled industrial processes. These would include metallurgical works, power stations, gas and coke works, ceramic works and lime works; such processes are considered to present special problems which would be best dealt with by the Alkali Inspectors, who are a central technical body of the Ministry of Housing and Local Government. Other industries and the railways would be dealt with by local authorities. Domestic chimneys are a problem because their smoke is seldom black, although they cause gross pollution. The control measure proposed for these is the establishment of 'smokeless zones' and 'smoke control areas' in which the domestic consumption of coal containing more than 20% of volatile matter would be prohibited.

The report recognises that the chief difficulties will be in making the railways and homes smokeless. Here the need is to accelerate the replacement of coal-fired locomotives with diesel or electric engines. The blackest spots are railway stations, engine sheds and goods yards. A concentrated effort to switch over to diesel engines for shunting would therefore bring very great benefit. British Railways are moving rapidly in the right direction; 250 diesels for shunting are already in use, and 800 are expected to be in use by 1957. The committee is, however, not satisfied with the rate at which coal-burning shunting engines are being replaced by diesels. The figure of 800, they point out, will represent only 30% of the present total of shunting locomotives in use, and they express the very firm opinion that no coal-fired locomotives should remain in use for shunting in any black area after 1960.

To keep the home fires burning, but without smoke, coal has to disappear from the nation's grates. It will have to be replaced by anthracite, coke and manufactured fuels which will need to be burnt in appliances which are economical. Greater use of gas and electricity in the home will play a part, and here the removal of purchase tax on these kinds of heating appliances is urged. As to the possibilities of district heating schemes, one short paragraph dismisses them as uneconomic, except in special circumstances.

A number of difficulties arise if householders have to change over from coal to smokeless fuels. Gas and electricity are dearer than coal for heating purposes, while the coke that is normally available will not burn in ordinary grates designed for coal, which will therefore need to be replaced. If all the households in 'black' areas were ultimately to convert to smokeless fuels such as coke, then conversion to new heating appliances would be necessary in some seven million households, costing around £10 per house. The report suggests that the Exchequer should bear 50% of the cost of replacing the 'banned' coal fires, and that the local authority should decide in each case how much of the balance it should contribute and how much should be borne by the householder.

The committee considers that a better quality coke that would be thoroughly satisfactory for household purposes can be produced at a slightly higher price than the average coke at present available. They also seem more optimistic than the general run of technical opinion on the supply of coals suitable for coking. Other smokeless fuels are being produced, of course, but their contribution to the 'clean air' programme will be limited, as their output is relatively small and their price is higher than many householders can afford.

There was criticism of this committee when it issued an interim report after four months' work that it was making no practical proposals. This was rather unfair on a report only intended to give some analysis of the 'smog' problem. Now, after fifteen months' work, the committee has made some eminently practical proposals. Their solution of the atmospheric pollution problem is a radical one, and it will take a singularly enlightened government to give full effect to the major measures proposed in the report.

SCIENCE SETS NEW STANDARDS OF AIRWORTHINESS

The problem of metal fatigue, believed by the scientists of the Royal Aircraft Establishment, Farnborough, to have caused the two Comet disasters, has led to important changes in the Certificate of Airworthiness requirements of new airliners. In short, the changes mean that a greater scientific approach is to be made to the pre-flight testing of future types of civil aircraft.

Firstly the Air Registration Board, the body responsible for the issue of the Certificates of Airworthiness, is to be reinforced by "members of scientific eminence". This and the other changes do not mean, of course, that there has been any suggestion of laxity in the 'C. of A.' requirements up to now. They have been as stringent as any in the world.

But the investigations at Farnborough, which have been described as among the "greatest scientific detective work in history", have thrown up in sharp relief the question of fatigue, particularly in pressurised cabins.

So, without waiting for any recommendations by Lord Cohen and his three technical assessors—Sir William Farren, Prof. W. J. Duncan and Air Commodore A. H. Wheeler—who are conducting the Comet Inquiry, the Air Registration Board have announced their new proposals. They have the approval of the Minister of Transport and Civil Aviation, and the Ministry of Supply is to co-operate in the fight against metal fatigue.

The addition of scientists to the A.R.B. is an important step. As at present constituted, the Board, headed by Lord Brabazon of Tara, is made up chiefly of representatives of the aircraft industry, the operators, and insurance interests.

Chief new requirement now before a new airliner receives its official blessing to fly with passengers is that a complete airframe will have to undergo a water-tank

The Comet 'Yoke Uncle' in the specially built water tank in which it was tested to destruction.

pressurisation test similar to that carried out at Farnborough on a Comet.

Farnborough scientists under Sir Arnold Hall believe that Comet G-ALYP, which was lost off Elba last January, broke up in the air at 30,000 feet following a fatigue failure in the cabin at the Automatic Direction Finder window in the roof. By piecing together like a giant jig-saw puzzle the pieces of the wreckage miraculously recovered from the sea by the Royal Navy, they thoroughly examined it and found traces of fatigue at that spot. But they also tested to destruction the Comet 'Yoke Uncle' in the specially built water tank, producing failures at points of stress concentration near the corners of window cut-outs.

The Farnborough test tank measures 112 × 20 ft., and is 16 ft. high. 'Yoke Uncle' was placed in this, its wings protruding through water-tight seals on either side. Nearby a special reservoir had to be constructed to hold the 200,000 gallons of water needed for the tests.

When the fuselage was submerged, another 100 gallons were pumped into the cabin of the aircraft, thus simulating the $8\frac{1}{4}$ lb. per square inch pressure difference experienced by a Comet at 40,000 ft. At the same time hydraulic jacks under the wings caused them to flex as they would do in flight. In five minutes the scientists were able to produce stresses equivalent to those experienced in a three-hour flight. In that short time the Comet went through all the stresses that would be encountered in half an hour of climbing to altitude, two hours of cruising and half an hour of descending. The cabin burst open at a window after the equivalent of about 9000 hours' flying.

It is this kind of fatigue test that is to be applied to all new airliners. Special tanks will have to be built, or the existing one at Farnborough modified to accommodate aircraft of different dimensions. The manufacturers of new aeroplanes will have to supply a whole airframe for the scientists to 'fly' in the tank until its breaking point is found. In this way it is hoped that the fatigue life of each aircraft will be found.

Airliners immediately affected are the later type Comets, the Mark II and III, and the Bristol Britannia. Arrangements are already in hand for a Britannia to start tank tests at Farnborough in February.

At the same time the Board will require yet another airframe for static load testing, while two more aircraft will be needed for flight trials. The effect, therefore, of the new Certificate of Airworthiness requirements will be that manufacturers will have to build four prototypes of each new airliner, two for testing on the ground—in the laboratory as it were—and two for flight tests. It is, of course, the usual thing now for aircraft firms to carry out static load tests on a new airframe, but the fatigue test is something entirely new.

Vickers-Armstrongs are building a water tank of their own at their Weybridge, Surrey, factory, and intend to carry out pressurisation tests on the Viscount which has already proved itself one of the world's most successful aeroplanes.

It is thought that the American authorities may follow the new lines of scientific testing which Air Registration Board is drawing up. Alongside the Board's new requirements there will undoubtedly be considerable intensification of research into fatigue.

Sir Lionel Heald, Q.C., representing the Crown at the Comet Inquiry referred to the importance of research on fatigue in aircraft. He spoke of the valuable work being done by the Air Registration Board, in the industry and in the Ministry of Supply on this phenomenon. "In particular, research on the problem of fatigue in high-grade light alloys has been sponsored for a long time by the Ministry of Supply, and work on the programme has been intensified during the past two or three years," he said. "The subject is continually before the appropriate Committees of the Interservice Metallurgical Research Council. Although the subject is a

difficult one and rapid results cannot be expected, it is fully recognised that the best brains and resources ought to be directed to it, and the Ministry of Supply has agreed to give the fullest co-operation in this work."

Sir Lionel Heald said that scientific representation on the Air Registration Board will be increased, and this step will undoubtedly be welcomed by everyone connected with British aviation.

A CARCINOGEN IN CIGARETTE SMOKE

A classic piece of cancer research was the proof that a complex organic chemical known as 3:4 benzpyrene can produce cancerous tumours. In these experiments a dilute solution of this compound, which is present in soot and coal tar, was painted on to the backs of mice, and in a matter of a hundred days malignant tumours developed on the skin of the animals.

The same substance has now been proved to be present in cigarette smoke, a fact which strengthens the case of the medical statisticians who reported a correlation between the incidence of cancer of the lung and cigarette smoking. The discovery is important, for one can now think in terms of the possibility of a causal connexion between the two things. Three British scientists made this discovery. They are R. L. Cooper, A. J. Lindsey and R. E. Waller, who report their findings in the issue of *Chemistry and Industry* for November 13, 1954 (p. 1418).

They estimated the amount of 3:4 benzpyrene in the smoke from 100 cigarettes to be of the order of 1 microgram. Working with this figure, they computed how much benzpyrene a heavy smoker would inhale into his lungs, and compared it with the quantity of this chemical which would reach the lungs through breathing an ordinary urban atmosphere polluted with soot and smoke. A person who smokes forty cigarettes per day would in the course of a year draw into his lungs about 150 micrograms of the chemical.

In the same period it is estimated that 200 micrograms would be taken in from the atmosphere. Most probably this benzpyrene is adsorbed on soot particles, and it may well be relatively inactive because the air undergoes some filtration in the nasal passages during normal breathing which prevents many of the larger particles reaching the lung. The benzpyrene of cigarette smoke is not associated with large carbon particles, and therefore the body's filtration mechanism does not seem likely to render the carcinogen inactive so far as the lungs are concerned.

SULPHONES AGAINST LEPROSY

It is only in the present century that any real progress has been made either in the treatment or control of leprosy. Recent progress has been most impressive, and it was encouraging indeed to hear one expert on leprosy, Major-General Sir Leonard Rogers, tell the Royal Society of Arts that nowadays medical reports from British territories in tropical Africa envisage the eradication of the disease as a possibility. That prospect has been opened up with the discovery and widespread use of the class of drugs called sulphones.

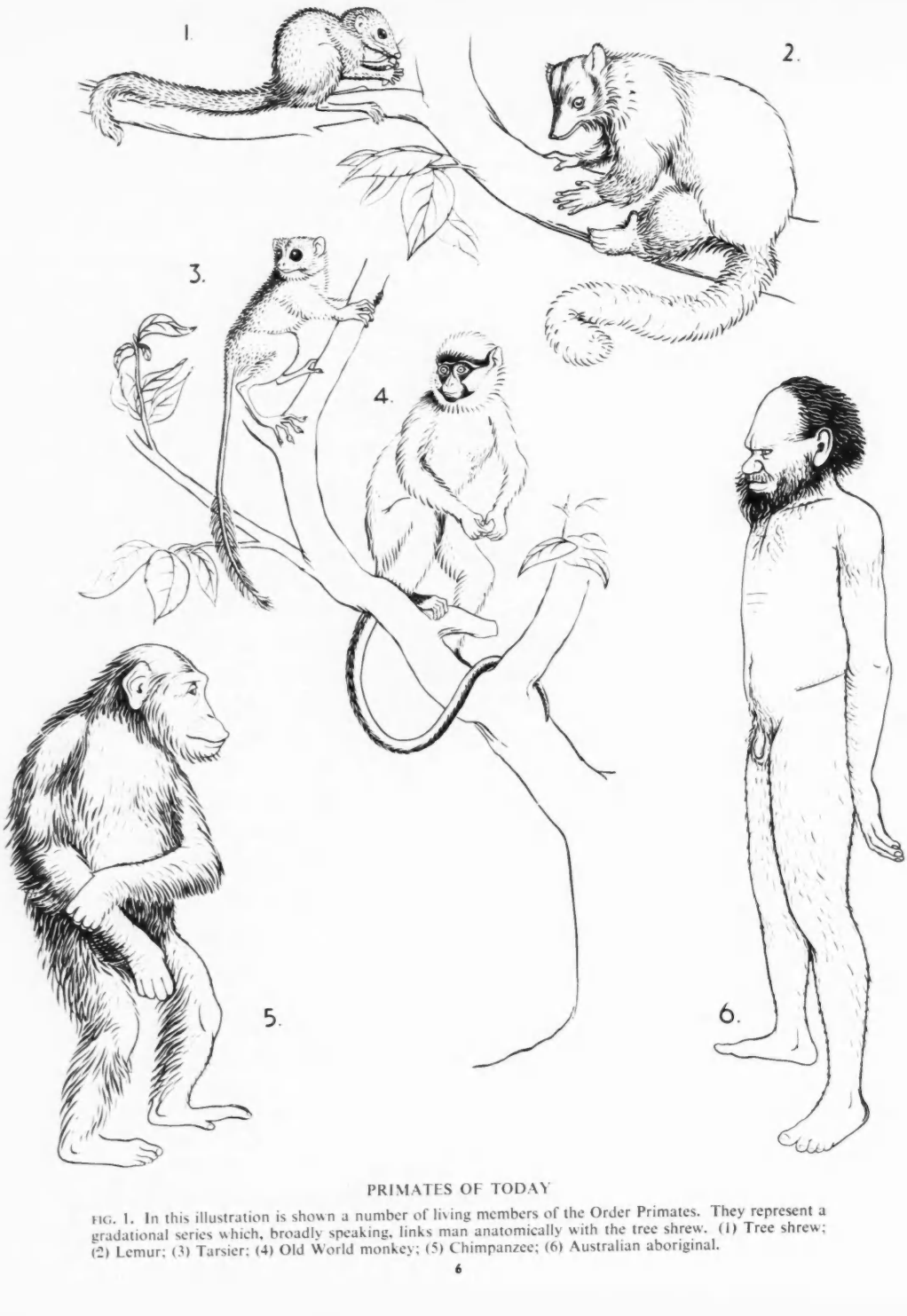
Leprosy is due to a kind of bacterium which closely resembles the organism that causes tuberculosis. They are in fact placed in the same genus—namely *Mycobacterium*. But the germ of leprosy has proved more vulnerable to attack by chemotherapeutic agents than the tubercle bacillus. The first substance to offer real promise was a compound called sodium hydnocarpate. This was derived from hydnocarpus oil, which had been regarded as a remedy for leprosy in India for a thousand years but which in fact, when tested scientifically, proved to be of little value since it failed to do more than slightly retard the progress of the disease. Sir Leonard Rogers was a pioneer of the treatment with sodium hydnocarpate, and he found that when repeated doses of this drug were injected into a patient symptoms of leprosy disappeared providing the treatment was given early enough. But it failed to do more than alleviate somewhat the symptoms in advanced cases. The importance of this early work was that it showed that chemotherapy could reach the bacterium of leprosy; if new compounds were synthesised and tested, perhaps one day the 'magic bullet' which would kill the bacterium without harming the patient would be found.

The first of the sulphones to show great promise against leprosy was promin. It was in 1943 that a group of workers at the Carville leprosarium in the southern United States established that promin given intravenously was far more effective against the disease than any drug previously tested. The next step was to find similar drugs that cost less and could be used on a large scale in tropical countries with a high incidence of leprosy. The compounds called sulphetrone and DDS (diasone) now enter the picture; the first drug is administered by injection and the second can be taken by mouth. With either of these sulphones lepers can be treated for a year at less than £1 per head.

In Nigeria DDS tablets have made possible what Sir Leonard Rogers called "unprecedented progress in the anti-leprosy campaign". He said that 50,000 patients were given regular treatment with DDS in the past three years. In his R.S.A. lecture Sir Leonard Rogers also gave details of the development of the campaign in other African territories, and he foresaw the eradication of this disease from the British Commonwealth in a very few decades if the essential staff and funds are forthcoming. Money is being made available from the Colonial Development and Welfare Fund, but Sir Leonard Rogers pleaded for a greater effort to spread the benefits which medical science has made possible in this connexion. His closing sentence was an inspiring clarion call: "What we now require is a modern crusade to provide the available means to save our Empire's children from the most cruel disease that human flesh is heir to!"

REFERENCE

The *Journal of the Royal Society of Arts* (1954, Vol. 102, pp. 987–1002) contains the full text of the lecture by Sir Leonard Rogers, who was one of the founders of the British Empire Leprosy Relief Association.



PRIMATES OF TODAY

FIG. 1. In this illustration is shown a number of living members of the Order Primates. They represent a gradational series which, broadly speaking, links man anatomically with the tree shrew. (1) Tree shrew; (2) Lemur; (3) Tarsier; (4) Old World monkey; (5) Chimpanzee; (6) Australian aboriginal.

REASON AND FALLACY IN THE STUDY OF FOSSIL MAN*

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This year marks the centenary of one of those seemingly chance occasions which eventually led to the conception of the idea of natural selection as the main basis of organic evolution. As is well known, this idea occurred practically simultaneously to the two great naturalists, Darwin and Wallace. It was a hundred years ago, on November 1, 1854, that Wallace landed in Borneo to spend several months in Sarawak, and, four months after his arrival (in February 1855), he wrote his essay: "On the law which has regulated the introduction of new species." Three years later, during an attack of malarial fever on one of the Molucca islands, while cogitating on his experiences in the tropical forests of the Far East, he records that "there suddenly flashed upon me the idea of the survival of the fittest. . . . In the two hours that elapsed before my ague fit was over I had thought out almost the whole of the theory, and the same evening I sketched the draft of my paper, and in the two succeeding evenings wrote it out in full, and sent it by the next post to Mr. Darwin." Darwin had in fact already arrived at precisely the same conclusions, and in support of them had accumulated a vast amount of detailed evidence.

The history of Wallace's wanderings in Sarawak has always been of special interest to me personally, for in the early part of my career I myself spent three years in the same region of Borneo, and took occasion to make a number of expeditions into the jungles and forests in search of some of the less common mammals which belong to the zoological Order, Primates, the Order (that is to say) which includes the zoological family called the Hominidae to which, by virtue of our anatomical structure, we ourselves belong. Borneo is a particularly interesting country for those interested in the Primates, because it is the natural habitat of so many different representatives of that Order. It is the home of the most primitive of those extraordinarily primitive Primates, the tree-shrews, as well as of other tree-shrews of a more highly organised type which show quite a number of lemur-like characters; of lemurs which combine in their anatomy a blend of features suggesting an intermediate position between tree-shrews and monkeys; of the curious little tarsier which in some respects is even more monkey-like; of many different kinds of tailed monkeys; of anthropoid apes represented by the smaller and more primitive gibbon and the larger and more man-like ape, the orang-utan; and lastly, of course, of several interesting varieties of *Homo sapiens*.

Meeting all these Primates (face to face, as it were) in their natural surroundings, one is bound to be impressed with the fact that they comprise a rather remarkable gradational series which, broadly speaking, links man anatomically with some of the most primitive placental mammals which exist today. Gradational series of this sort, of course, had attracted attention long before the days of Darwin and Wallace, and they provided one of the first clues which gave rise to the idea of an evolutionary process. Indeed it was the subsequent elaboration of this type of evidence which led on (almost inevitably, as it seems in retrospect) to the discovery of the principle of natural selection in relation to the origin of species.

THE CRUCIAL EVIDENCE FOR EVOLUTION

Now, however extensive and compelling it may be, the evidence for evolution based on the study of creatures living today can only be indirect evidence. Direct evidence, on the other hand, must depend on the actual demonstration from the fossil record of a succession of transitional stages representing the transformation in geological time of an ancestral into a descendant type. We may perhaps put it in this way. The evidence from the comparative anatomy of living forms, together with the geographical distribution of local species and varieties which exist today, demonstrates that evolution *might* have occurred. The evidence provided by a study of the process of natural selection, experimental genetics, population statistics and so forth, establishes quite clearly that the machinery exists whereby evolution *could* have occurred. But that evolution actually *did* occur can only be scientifically established by the discovery of the fossilised remains of representative samples of those intermediate types which have been postulated on the basis of the indirect evidence. In other words, the really crucial evidence for evolution must be provided by the palaeontologist whose business it is to study the evidence of the fossil record.

It is quite well known that the fossil record of some groups of mammals is sufficiently complete to provide a fairly clear picture of their evolutionary history, for in such cases the extinct types arrange themselves in a gradational series which the geological evidence shows to be also a *time* sequence. So far as man's ancestry is concerned, however, the fossil record is far from complete. On the other hand, it is by no means negligible. But, in spite of this, the interpretation of the record still gives rise to astonishingly diverse opinions among anthropologists, and it is a matter of importance to inquire why this should be so. No doubt one of the reasons is that it is extraordinarily difficult to view the evidence quite objectively. For, after all, the problem of our own origin is a very personal problem, and even the scientist may not find it easy to clear his mind entirely of an emotional element when he considers the evidence in detail. One gets the impression that this tends to affect arguments about fossil remains in quite different ways, such as claiming for modern man a much greater antiquity than is actually warranted by the geological evidence, or claiming that certain extinct types are much more apelike than they really are. There is no doubt, also, that the element of emotional

* *This is the substance of an evening discourse delivered during the Oxford meeting of the British Association: and is printed by permission of that organisation.*

prejudice has been increased in popular expositions of the origin of man by the tendency to compare him in his anatomical structure only with modern anthropoid apes such as the gorilla, chimpanzee and orang-utan. As a result, the idea has unfortunately got about that he is actually supposed to have been descended from a creature almost precisely like these apes of today. But this is a gross misconception for which there has never been the slightest foundation. It is true that in quite a number of anatomical characters of the skull, skeleton, teeth, viscera, brain, etc., man shows a closer resemblance to the modern anthropoid apes than he does to any other group of mammals, and, by analogy with what we know from the fossil record of the evolutionary history of other groups of mammals, this suggests the probability that the anthropoid ape family and the zoological family which includes man (the Hominidae) were *ultimately* derived from a common ancestral stock by a process of divergent modification. But, if this is so, we need to remember that when we compare anatomically man and the anthropoid apes of today, we are comparing the terminal products of two separate (and in many ways contrasting) lines of evolution which presumably diverged from each other at quite a remote geological period. Failure to recognise this rather obvious point has certainly led to a certain amount of confusion in some discussions on human origins.

This brings us to one of the most essential questions relating to the general problem of evolutionary relationships and evolutionary lines of development. How is it to be determined, simply on the basis of comparative anatomy, that one type of animal is closely related to another, or perhaps that the relationship at the most is only a very distant one? The answer is that degrees of relationship are inferred on the basis of resemblances or differences in anatomical characters. If two types very closely resemble each other in a complex pattern of anatomical details of the skull, skeleton, teeth, etc., it is inferred that their genetic relationship is correspondingly close. Evidence of this kind by itself, of course, is indirect evidence. But it has been found to conform with the evidence of the fossil record in many instances and thus may be accepted as reasonably sound. However, in attempting to assess degrees of relationship it is most important to recognise that not all anatomical resemblances have the same significance, and they may not therefore be treated as though they all had the same quantitative value. Everyone agrees that man is a mammal, for in his anatomical structure and physiological functions he falls within the zoologist's definition of a mammal; indeed, he is constructed on the same basic anatomical and physiological principles as even the lowliest of mammals which exist today. But this does not indicate a very close relationship with the lowliest mammals; in fact it only indicates a very remote relationship indeed—the result of the inheritance of common mammalian characters going back perhaps as much as a hundred million years. It is also agreed that man is a member of the Primates, for in his anatomical structure he accords with the zoologists' definition of this mammalian Order, and for the same reason he is grouped with the anthropoid apes with which he has many anatomical characters in common. But the fact that, for example, he has the same number of teeth as a chimpanzee, and also the same bony elements of the skeleton, the same basic pattern of convolutions of the brain, the same general disposition of muscles and so forth, by no means necessarily indicates a very close and immediate relationship; on the contrary, it can only be taken to suggest that man and the chimpanzee have inherited such common characters from a common ancestral stock, and, as we shall see, on the present fossil evidence their origin from this presumed ancestral stock must have occured at least several million years ago. Such characters may conveniently be called 'characters of common inheritance'. But when different lines of evolution branch out independently of each other to form *separate* groups (such as those represented by the different families of zoological classification), each of them—because of its different genetic constitution and therefore different potentialities—acquires its own special and peculiar pattern of anatomical characters by which it comes to be distinguished as a group of closely related types.

CHARACTERS OF INDEPENDENT ACQUISITION

Characters of this sort may be called 'characters of independent acquisition', and they obviously have a far greater value for assessing degrees of relationship as between one group and another. Thus, if the inference from comparative anatomy is correct that the anthropoid ape family and the family of the Hominidae (which includes not only modern man but also his predecessors) have ultimately sprung from a common ancestral stock, it is quite clear that they have followed very different (and in some ways quite opposite) trends of evolutionary development. For example, the ape family gradually became adapted to one particular mode of arboreal life with associated changes in the proportions of the limbs, and they also developed quite special features of the skull and dentition. All these, taken together, comprise a pattern of characters which was acquired independently by the anthropoid ape sequence of evolution, and they are peculiar to, and therefore diagnostic of, this sequence and serve to distinguish quite sharply its earlier and later representatives from the hominid sequence of evolution.

Contrariwise, the hominid sequence of evolution has been distinguished by its own special trends of evolutionary development, as shown by quite unique characters of the skull, dentition and limbs; these are the characters of independent acquisition whereby all the subsidiary ramifications of human evolution contrast strongly with those of anthropoid ape evolution. Quite obviously, if the commonly accepted picture of hominid evolution is correct, then the representatives of the earlier phases of this evolution must have shown many primitive features which were later superseded in the progressive changes culminating in modern *Homo sapiens*—for example, the fossil evidence now makes it fairly clear that the expansion of the brain which is so characteristic of our own species was a comparatively late phenomenon of hominid evolution (for there is no evidence that it occurred before the beginning of the Pleistocene period, that is to say, the period of the Great Ice Age). But even before the expansion of the brain became at all obtrusive we might expect to find evidence of the incipient

development of *other* characters of independent acquisition diagnostic of the Hominidae, which would make it clear that these early types were definitely hominids and not anthropoid apes.

There is one other point to which I must refer in these preliminary remarks, and that is the use and misuse of the colloquial terms 'man' and 'human' in discussions of evolutionary origins. Not even anthropologists always employ these terms consistently, but the main difficulty is that they are terms which in ordinary usage are commonly taken to imply very much more than the meaning attached to them by anatomists or biologists when they are only considering man in a strictly anatomical or biological sense.

It is, in fact, pretty well impossible to give a satisfactory definition of man which will satisfy all schools of philosophy. In its religious connotation, for example, the concept of *Man* is taken to imply the conjunction of two quite distinct orders of being; in his physical body and those aspects of emotional experience which may be determined by purely physiological processes he is a member of the material or —more specifically—the biological world; and by virtue of the fact that he is believed to possess a soul or spirit and that he is capable of responding to beauty, of making moral judgments, and of apprehending the divine, he is a member of a non-corporeal order of reality. It is possible that not all of us feel completely satisfied with such a dualistic interpretation of *Man*, even when stated in terms which seek to avoid the implicit dualism. But it is a view widely held by men of great intellectual distinction, and it is therefore a view which demands respectful consideration, to say the very least. Matthew Arnold once wrote: "Man hath all that Nature hath, but more," and in this lecture I am, of course, only concerned to discuss those physical attributes of man which he shares in common with the rest of Nature. The fact is that the anatomist is not qualified *as an anatomist* to define man as *Man*. He is only competent within his own special field of study to define man in anatomical terms as one of the species of the animal world—*Homo sapiens*. It is for this reason that I have come to the conviction that in discussing the evolutionary origin of our own species, the biologist should avoid altogether the terms 'man' and 'human'—except only where there can be no possible misunderstanding about what he means by them. Undoubtedly, also, we can approach this whole problem with much greater objectivity if we confine ourselves rather strictly to the scientific terms of zoology, such as *Homo* (meaning the generic group of which *Homo sapiens* is one of the species —in fact, the only surviving species) and the Hominidae (an inclusive term meaning the zoological family of which *Homo* is one of the genera).*

In so far as, biologically speaking, *Homo sapiens* is one of the mammalian species (and thus may be presumed to be the product of an evolutionary process similar to that which is known from the fossil record to have been the case with other groups of mammals), the questions naturally arise—what precisely is his relationship to the other members of the zoological Order to which (by virtue of his anatomical structure) he belongs, and how came he to acquire those distinctive characters which distinguish him from all other mammals, such as his large brain and his ability to stand and walk erect? These are questions which can only be finally answered by the evidence of the fossil record.

FIG. 2. *Pithecanthropus*. A tentative reconstruction of the appearance of this extinct type of hominid which inhabited the Far East in the Early and Middle Pleistocene. Fragmentary remains of the skeleton indicate that the limbs were constructed as in modern man. In contrast, the brain-case was small, the forehead retreating, and the jaws large and prominent.

What, now, do we actually *know* from the fossil record of the origin of mankind? Not nearly so much as we should like to, and not nearly so much as some people seem to suppose. The fossil record has certainly become much more abundant as the result of discoveries in recent years, so that it is no longer true (as it used to be facetiously observed) that there are actually more students of fossil man than specimens for study and argumentation. But it is still meagre in comparison with that of some other groups of mammals, so that, while it certainly provides rather positive indications of the main trends of evolution, many of the details have to be filled in quite provisionally for the present, with the ready admission that new discoveries may require quite considerable modifications of current interpretations of the evidence.

* I cannot help feeling that, if in the earlier days of evolutionary discussion a clear distinction had been made between what may be termed 'anatomical and physiological man' (i.e. the biological species, *Homo sapiens*) and the concept of *Man* in its wider philosophical context, some of the more distressing controversies of those days might perhaps have been avoided.

THE ANTIQUITY OF HOMO SAPIENS

We know that in Europe men of modern type (*Homo sapiens*) were certainly in existence in well-organised communities and with quite an elaborate culture some 10,000 years ago in the Mesolithic period. Indeed there is quite good evidence that some of them had even invaded the American continent by that date. We also have evidence that still earlier communities of *Homo sapiens* occupied Europe about 15,000 years ago. We are fairly certain of this because the antiquity of some of the prehistoric cave paintings discovered in France—dating from the Magdalenian period of palaeolithic culture—has been estimated by the radioactive carbon method, and the skulls and skeletons of the people living at that time are indistinguishable from those of *Homo sapiens*. Indeed I do not think they could easily be distinguished from modern Europeans. We can go further, for we know that men of the *Homo sapiens* type were living in a still earlier cultural period, the Aurignacian, and on the geological evidence this allows us with some assurance to carry palaeolithic communities of *Homo sapiens* back to a period not long after the climax of the last glaciation of the Ice Age—probably about 20,000 years ago. But if men of modern physical type had already been able to develop a relatively advanced culture in Europe as far back as this, it might be supposed that, as a biological species, *Homo sapiens* must have a still greater antiquity. In fact, there is some fossil evidence in support of this conjecture.

A number of human skulls, or parts of skulls, have been excavated from deposits in Europe which were evidently laid down *before* the last major glaciation of the Ice Age—that is to say, during the preceding warm interglacial period. The geological evidence for this is reasonably sound, and, so far as we can judge by the fossilised bony remains, the latter belong to the same species as ourselves, though it may well be that if we could see them in the flesh we should recognise them as a distinct race. Now, this carries *Homo sapiens* in Europe back something like 50,000 years, though it is important to note that this is only an approximate estimate based on general considerations of a geological nature. But we do have confirmation of an antiquity of this order for the species from the radioactive carbon analysis of a specimen of peat from a site at Florisbad (in South Africa) where a skull of *Homo sapiens* type was discovered in 1933. The peat (with which the skull was closely associated) showed no radioactivity, from which it has been concluded that it was probably deposited more than 40,000 years ago.

Lastly, there is some evidence that *Homo sapiens* was present in Europe even in the penultimate interglacial period, a phase of the Ice Age which could hardly have occurred less than 100,000 years ago. This evidence is mainly based on the Swanscombe 'skull', two parts of which were discovered in gravels of the Thames valley in 1935 and 1936. But, although the geological and archaeological estimates of the antiquity of these gravels are reasonably sound, there are two reasons for a certain amount of caution in regard to this specimen. In the first place it is an isolated specimen, and conclusions based on it should await final confirmation by further discoveries. Secondly, the so-called 'skull' consists of only two bones of the brain case—the occipital and the left parietal. Now, it is a fact that a most searching study of these bones by anatomical and statistical methods has failed to show any difference at all from those of modern *Homo sapiens*. It is probable, therefore, that Swanscombe man *was* an individual of this species. But we cannot be quite certain, and we need to be aware here of a fallacy which not infrequently obtrudes itself in discussions on fragmentary fossil remains; that is the fallacy of assuming that there is such a precise correlation between the anatomical features of different parts of the body that it is possible with certainty to infer the *whole* structure from only a portion of it. In fact, this so-called 'law' of the correlation of parts is a rather dangerous pitfall, and has led more than one anatomist to quite misleading conclusions. So far as Swanscombe man is concerned, it must be freely admitted that the further discovery of other parts of the skull and the skeleton may show that he was rather distinct from *Homo sapiens*.

There is another fallacy to which I must refer, and that is a most unfortunate tendency to over-emphasise so-called primitive features in these ancient representatives of *Homo sapiens*, a tendency which often seems to be the result of subjective impressions influenced simply by the supposed antiquity of the specimen, or because the investigator has not realised how variable some features are even in modern *Homo sapiens*. For example, it has been claimed that in some respects the fragmentary skull of Swanscombe man shows primitive features which are not to be found in modern man, though (as we have just seen) a systematic study of the skull with adequate comparative material has failed to demonstrate anything of the sort. But one of the best illustrations of this point is the famous Galley Hill skeleton, which was discovered in 1888 and was held by some authorities to be of very great antiquity. One or two anatomists of high distinction persuaded themselves that they could recognise some very primitive features in this specimen, particularly in the shape of the lower jaw. Moreover, an apparent exhaustive study of the thigh bone involving an elaborate statistical comparison of a number of measurements and indices had even led to the conclusion that it was quite distinct from modern man, with the further suggestion that in some respects it seemed to approach the apes. But in recent years it has been determined, largely as a result of the analysis of its flourine content, that the Galley Hill skeleton was a burial of comparatively recent date—perhaps the remains of a Neolithic man, or possibly even a later interment. How is this discrepancy of evidence from the statistical side to be explained? This is rather an important question, for statistical tables (particularly to anyone who is not a statistical expert) are apt to convey an impression that conclusions based on them are final and indisputable. But it has now come to be realised that the application of statistical methods to the study of zoological relationships of fossil remains is open to rather serious fallacies, depending on the statistical methods used, on the actual number of measurements taken, on whether the measurements compared are really strictly equivalent in the morphological sense, on whether they differentiate between what I have called characters of common inheritance and characters of independent acquisition, and so forth. It has also been demonstrated that if the individual characters

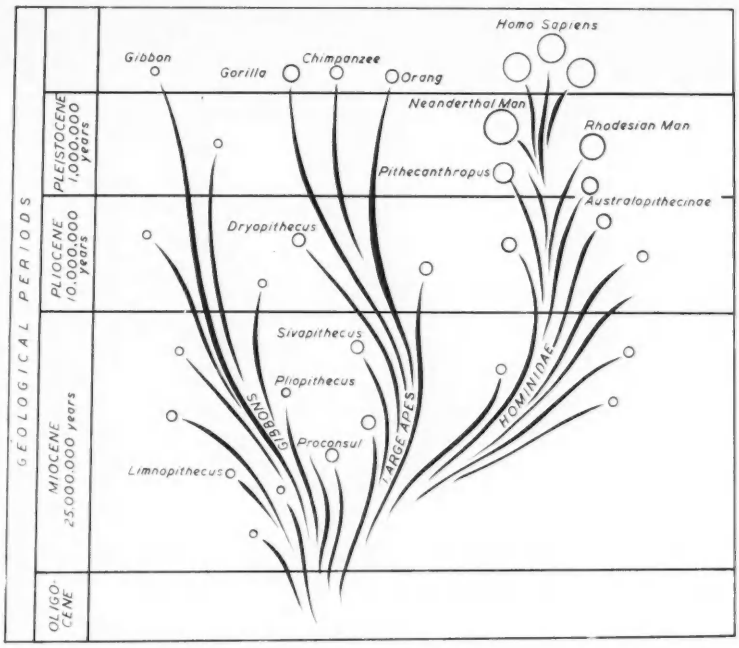


FIG. 3. A 'family tree' that indicates the relationships of the Hominidae and the anthropoid apes so far as these can be inferred from the fossil evidence at present available. The circles are intended to represent approximate differences in the relative size of the brain. Note that the brain apparently did not begin to undergo the expansion characteristic of modern man until the Early Pleistocene. This diagram is also designed to emphasise that the evolutionary sequences of the Hominidae and the anthropoid ape family are radiations rather than simple linear sequences, involving the development of many collateral lines of which probably only a few have yet been discovered in the fossil record.

and measurements of a bone or a tooth are compared independently one by one, as isolated abstractions, instead of comparing them in their totality as integral components of a total *pattern* (which can be done by the very complicated method of multivariate analysis), entirely different (and sometimes very misleading) conclusions may be reached. In the case of the Galley Hill thigh bone, the answer is fairly simple, for in the statistical study of this bone comparison was made with the thigh bones from a collection of skeletons of 17th-century Londoners, and it seems to have been assumed that these could be taken as representative of *Homo sapiens* as a whole. But obviously the comparison must be made with samples of all the main varieties of *Homo sapiens* before it can be legitimately concluded that there is a distinction from 'modern man'.

I must here make a passing reference to the well-known 'Neanderthal man', although this extinct type almost certainly had nothing to do with the origin of modern types. But he illustrates rather well the need for caution in drawing conclusions from too scanty fossil evidence. When remains of Neanderthal man were first discovered and described, he was regarded by some authorities as essentially a primitive type linking *Homo sapiens* with the apes. As a provisional interpretation of the evidence then available this was perhaps not unreasonable. For he was known to be ancient (living in the period of the last glaciation of the Ice Age) and he showed a number of apparently primitive characters such as a retreating forehead, huge brow ridges and a large, chinless jaw. However, as we have already seen, we now have evidence that *Homo sapiens* had already come into being at a still earlier time. It appears, therefore, that Neanderthal man could hardly have been ancestral to *Homo sapiens*, and it is now generally held that he represents a secondary and somewhat aberrant line of evolution which finally came to a dead end.

THE OLDEST IMPLEMENTS

We have seen that there is quite good evidence that *Homo sapiens* goes back to the last interglacial period, and there is some evidence (which needs to be confirmed by further discoveries) that he also existed in the preceding (second) interglacial period. What, now, about the evidence of still earlier types of the hominids? If man is defined as a tool-making hominid, we know that he extended back to the earliest part of the Pleistocene period, for his stone implements have been found in geological deposits of this age in many parts of the Old World. But what of his physical characters? There is quite sound evidence from fossil remains that hominids of a very primitive type were in existence in the Far East during the Middle and Early Pleistocene, for these remains have been found in fair numbers in Java and China. But he was very different from *Homo sapiens*. Skulls, or parts of skulls, show that these early types had much smaller brains—on the average not very much more than two-thirds the size of the brain of modern man, they had retreating foreheads, huge brow ridges, massive jaws and very large teeth. Indeed so different were they from modern man that they are usually recognised as a distinct genus which has been called *Pithecanthropus*.

At one time there was a good deal of animated discussion about the exact status of these fossil types, and some authorities even supposed they were really apes—a sort of giant gibbon. Now, if you confine your attention and limit your measurements to just those *primitive* characters of the skull and jaws of *Pithecanthropus* in which this ancient

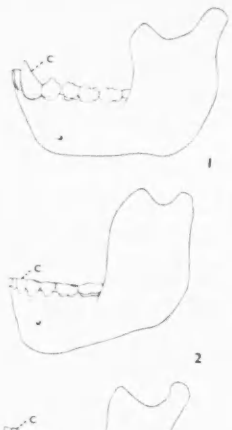


FIG. 4. The lower jaws of (1) an orang-utan, (2) one of the fossil Australopithecinae from South Africa, and (3) a modern Australian aboriginal. Note that the australopithecine canine (c) is very different from that of an ape in shape as well as size; it evidently soon wore away at the tip so as to become level with the other teeth as happens to the canine teeth in modern man.

hominid appears to resemble apes—and if, moreover, you compare them only with (say) modern Europeans—you could no doubt make out quite a plausible case for arguing that he *was* an ape. But such primitive characters are evidently characters of common inheritance which (as we have seen) do not by themselves differentiate between the anthropoid ape family and the Hominidae, since in both groups they must be presumed to have been derived in the much more remote past from a common ancestral stock. And if this evolutionary divergence has in fact taken place, such characters may be expected to be more obtrusive in the *earlier* representatives of the hominid line of evolution, before, that is to say, the trends of evolutionary development which are distinctive of this line had manifested themselves to the degree seen in later representatives. But it does not mean, of course, that *Pithecanthropus* was an ape—or even that he was nearly related to the apes. For, in fact, this fossil type shows very many characters which are quite distinctive of the Hominidae, that is to say, a combination of characters which the members of this family acquired in common with each other *after* it had become completely segregated in its evolutionary history from all other Primates (including the ape family). Such characters are seen in the larger brain, many details of dental anatomy, and particularly in the limbs. The limb bones which have been found are few and most of them are rather fragmentary, but so far as they go they show that the limbs of *Pithecanthropus* were not only entirely different from those of the known apes, but were fashioned almost precisely as they are in *Homo sapiens*. In other words, it appears that in the gradual progress of the hominid line of evolution, the modifications of the limbs for an upright posture were completed long before the brain, skull, jaws and teeth had undergone the refinements seen in *Homo sapiens*.

We know, too, from excavations in China that *Pithecanthropus* had already mastered the technique of fabricating stone implements, and even knew the use of fire for domestic purposes. Thus, in spite of his relatively small brain, he was certainly endowed with an intelligence which can properly be termed 'human'. It is a matter of some interest to conjecture how many years ago *Pithecanthropus* lived in the Far East. Unfortunately, this can for the present be no more than conjecture, for although we know he was already in existence in the Early Pleistocene we have as yet no means of dating this period of geological time with any certainty in terms of years. Estimates based on indirect evidence (mainly by reference to the relative lengths of the intermittent glaciations and interglacial periods) suggest an antiquity of as much as half a million years, but I must insist again that these are only approximate estimates which may quite likely need to be revised in the light of future knowledge.

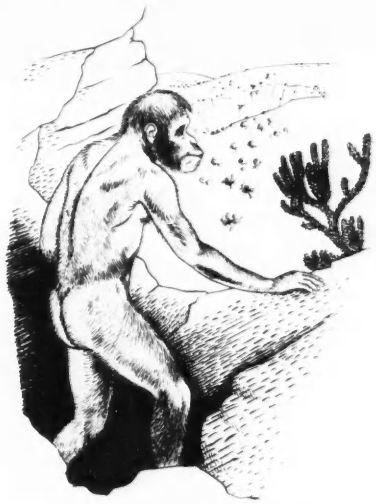
So far, there is no reliable evidence that *Homo sapiens* had appeared on the earth as far back as the Early Pleistocene. It seems, therefore, that *Pithecanthropus* was a precursor of *Homo sapiens*, and the conclusion naturally suggests itself that this extinct type of hominid was actually ancestral to *Homo sapiens*. This is not to say, of course, that the group of individuals whose remains have been found in the Far East was itself the ancestral stock from which we ourselves are descended. But other representatives of the same type may have been. No doubt the evidence of the fossil record is still far too scanty to establish firmly such a conclusion. It can only be at present a provisional hypothesis, but it is an hypothesis which is reasonably consistent with the few facts at our disposal so far. And it does fit in very well with the postulates of human evolution which have been based on the indirect evidence of comparative anatomy. But if these postulates are sound, then *Pithecanthropus* must presumably have been preceded by a still more primitive type of hominid—with still smaller brains, larger jaws and so forth. Is there any fossil evidence that such a type ever existed? The answer to this question is to be found in the remarkable discoveries which have been made during recent years in South Africa of the remains of creatures to which (as a group) the somewhat cumbrous name Australopithecinae has been given. Unfortunately it is very difficult to give them a less pedantic name without misleading implications, though, because of the curious mixture of anatomical features which they show, they are sometimes referred to as 'ape men' or 'near men'.

The remains of the Australopithecinae so far discovered are surprisingly numerous; they include many skulls of individuals of all ages from babyhood upwards, large numbers of jaws and hundreds of teeth, several limb bones, the greater part of an articulated spinal column, and three remarkable specimens of the pelvis. In the absolute size of their brain these extinct creatures were hardly advanced beyond the level of the large anthropoid apes of today. With the small brain-case and the huge jaws, indeed, they do show a very ape-like appearance. In fact, if you choose

to define an ape merely by reference to the size of the brain, then you would call them 'apes'. But I think most authorities are now agreed that this would be misleading, for there are other reasons for concluding that they were not on the ape line of evolution at all.

Here we come up against the same sort of problem which confused some anatomists in their attempts to interpret the significance of *Pithecanthropus*, the problem of differentiating between primitive characters which are simply characters of common inheritance signifying an *ultimate* derivation from an ancestry in common with the apes, and those characters which are diagnostic of the Hominidae for the reason that they were acquired independently by this line of evolution *after* it had become completely segregated from the ape line. The fact is that the Australopithecinae do present a very complex pattern of morphological characters which are otherwise only found in the Hominidae, and which are very different indeed from the characters of independent acquisition which are diagnostic of the anthropoid ape line of evolution. For example, the dentition is essentially hominid. It is true that the grinding teeth are very large, but not larger than they are in some of the jaws of *Pithecanthropus*. Indeed, in all fundamental characters the teeth are so like those of *Pithecanthropus* that I must admit to you that I do not know of any certain way by which I could distinguish them. On the other hand, they are so entirely different from the teeth of apes (either living or extinct) that they are quite easily distinguishable from these.

In many details of the skull, also, the South African fossils are quite different from apes, and, again, in these particular respects they are similar to, or approach, the hominid type of skull. These details include (in combination) the height of the brain-case, the forward position of the occipital condyles (by which the skull articulates with the top of the spine), the shape of the jaws and chin region, the construction of the ear region of the skull and the muscular markings at the back of the skull (on the occipital bone). This last feature is of very considerable importance in its functional significance. In all the known large anthropoid apes the neck muscles extend their attachment far up on the back of the skull (often forming here a prominent shelf-like 'nuchal crest') in order to hold up the head in position at the front end of a forwardly sloping spinal column. In modern man, the erect posture eliminates the need for these powerful neck muscles, for with the adoption of such a posture the head becomes rather nicely balanced on the top of the vertical spinal column. In the South African fossils (and this is now known for certain from quite a number of specimens found at different sites in South Africa) the muscular markings on the back of the skull show the human arrangement—that is to say, the attachment of the neck muscles only extended up for a short distance. In other words, it suggests that in the Australopithecinae the skull must have been balanced on the top of the spinal column in a manner rather similar to ourselves, and that in their habitual posture they must have approximated quite closely to the erect posture characteristic of *Homo*. There is corroborative evidence of this in the forward disposition of the occipital condyles on the base of the skull, and (still more convincingly, as we shall see) in the construction of the pelvis and the lower end of the thigh bone.



AUSTRALOPITHECUS

FIG. 5. *Australopithecus*. A tentative reconstruction of the appearance during life of one of this type of fossil hominids which inhabited South Africa in the Early Pleistocene. The feet are not shown in this illustration for the reason that the fossil evidence so far available is not sufficient to determine how they were constructed. Modified from a painting by Maurice Wilson.

I ought to mention here that in some of the largest australopithecine skulls (found at Swartkrans) the top of the brain-case is marked by a low median crest which is related to the growth of the temporal muscles that move the massive jaws. This is simply the result of the combination of a small brain-case with large jaws. But in one of the earliest of these specimens to be discovered the occipital region at the back of the skull was missing, and it was thought by some that the median crest must have extended back into a high nuchal crest just as it does in gorillas, and that therefore the neck muscles must have been similarly extensive and powerful. This illustrates the grave danger (to which I have already referred) of relying too rigidly on the so-called 'law' of the correlation of parts, for, as we now know from other skulls with a median crest on the top and with the occipital region preserved at the back, the latter shows that there was in fact no high nuchal crest of the gorilloid type—the muscular markings for the neck muscles are situated low down in the typical hominid fashion. In possessing a median crest on the top of the skull *without* a high nuchal crest on the back of the skull, the Australopithecinae are unique among Primates. But this is simply because they represent an early phase in the evolutionary development of the unique character of the Hominidae—the erect posture and gait—when the temporal muscle was still very large and the brain-case relatively small.

Now let me refer to the evidence of the thigh bone and pelvis. Several specimens of the thigh bone of the South African fossils are now known and have been studied in

considerable detail. A simple inspection is enough to show that the lower end of the bone (which helps to form the knee joint) is constructed quite differently from that of the modern anthropoid apes, and this has been confirmed also by a statistical study of relative measurements. In fact, it shows a pattern of anatomical features which is similar to that of hominids and which is evidently also related to an upright posture and gait. The three specimens of the pelvis so far discovered provide the final confirmation of this conclusion.

This evidence is of particular importance, for there are certain anatomical features of the human bony pelvis which sharply distinguish it from all apes, and indeed from all other mammals. Together, they represent an adaption to the mechanical requirements of an erect posture, and they include (among other things) the great relative breadth of the iliac blade, the lengthening of the iliac crest for the more extensive attachment of the trunk muscles, the backward displacement of the area of attachment of certain muscles so that they can be effectively used in upright walking, the rotation and downward shifting of the joint through which the weight of the body is transferred from the spinal column to the lower limbs, the development of a very distinctive bony eminence marking the attachment of a powerful ligament which is required to stabilise the hip joint in the erect position, and so forth. None of these features is found in combination—or indeed even singly—in the ape type of pelvis. Now, the remarkable fact is that the pelvic bones of the South African fossils all show every one of these features consistently; in other words the pelvis is constructed fundamentally on the hominid plan, and it seems that this can only mean one thing—that the pelvis was adapted to the requirements of an erect, bipedal posture and gait. On the other hand, they do show certain differences from the pelvic bones of *Homo sapiens*, and we do not suppose, therefore, that in these ancient hominids the erect posture and gait had been perfected to the degree found in modern man. Indeed it would be very surprising if this were the case, considering the very primitive characters which they still retained in their skull, jaws and brain. It is interesting to note, lastly, that the anatomical evidence of bipedalism is entirely consistent with the geological evidence of the environment in which the Australopithecinae lived, for this evidence shows quite positively that they were not forest dwellers leading the type of arboreal existence for which the modern anthropoid apes are adapted—they lived in open country very similar to the veldt-lands of the Transvaal today.

I have referred to the Australopithecinae as hominids. And indeed on the criteria of their anatomical structure (and in spite of their small brain capacity) they must be included in the Hominidae, for the complex pattern of progressive features found in their skulls, jaws, teeth and limbs makes it quite clear that they were already well advanced along the direction of evolutionary development distinctive of the Hominidae as a zoological group—and quite opposite to the direction which was followed by the ape family in *its* evolutionary development.

If the anatomical evidence for the hominid status of the Australopithecinae is so clear, you may wonder why there should have been any dispute about them. Apart from the fact that discoveries of fossil remains of the precursors of modern man always have (and probably always will) become the centre of animated argumentation, the reason no doubt is to be found in the fallacies which seem so difficult to avoid in controversies of this kind, and to some of which I have already referred. Thus, there is the fallacy in the assessment of zoological relationships of confusing characters of common inheritance (that is to say, characters which are common to two divergent evolutionary groups simply because they have been derived in the distant past from a common ancestry) with those of independent acquisition (that is to say, characters which are developed *independently* in each evolving group and thus serve to distinguish the one from the other), the fallacy of comparing single characters as isolated abstractions instead of comparing integrated *patterns* of characters, the fallacy of relying on inadequate statistical methods, and the fallacy of confusing the zoological term 'hominid' with the colloquial term 'human'.

THE PREHUMAN PHASE

This last fallacy has evidently led to a great deal of misunderstanding. The zoological classification of the South African fossils as one of the branches of the Hominidae must not, of course, be taken to imply that they were 'human' in the sense that this term is ordinarily used, for we have so far no evidence that they had any of the distinctively human attributes such as the faculty of speech or the ability to fabricate implements. In order to avoid confusion, they may (for the present, at any rate) be appropriately referred to as representatives of the prehuman phase of hominid evolution.

Could the Australopithecinae have been the evolutionary ancestors of later hominids—including *Homo sapiens*? It has been argued that this could not be so because they existed too late in time, for the geological evidence indicates that the individuals whose remains have been found in South Africa lived in the Early Pleistocene (that is to say, more or less contemporaneously with the larger-brained *Pithecanthropus*). But here we have exemplified yet another common fallacy in discussions on human evolution—the assumption that particular fossils which have been discovered are necessarily the *earliest* representatives of the group to which they belong. As a zoological group, the Australopithecinae must surely have been in existence well before the Early Pleistocene, for we have evidence that already by that time they had become differentiated to form at least two different varieties, or even species. Thus it is clearly possible that the *group as a whole* may have provided the ancestral stock from which more advanced hominids were derived. Nevertheless, this suggestion of an ancestral relationship is, of course, only a provisional hypothesis for the present, seeing that the fossil record is still far too incomplete to demonstrate it with any degree of certainty.

In one sense it might appear that the primitive characters of the Australopithecinae—such as the small brain and the large jaws—emphasise the closeness of man to the apes in their evolutionary relationship. But a more careful appraisal of the anatomy of these fossil creatures brings one to a rather different point of view, for it is now clear that, in spite of these primitive characters, they were

already at that early time very different from apes in many fundamental hominid characters of the skull, teeth and limbs. And, from what we know of the rates of evolutionary change in general, this makes it certain that the line of hominid evolution must have become a separate and independent line at a much more remote time. In other words, if anything, the South African fossils emphasise the extent of the *divergence* of the hominid line of evolution from the ape line of evolution.

This brings us to one of the ultimate questions—how long ago do we suppose that the hominid line of evolution did become segregated from the presumed ancestral stock which also gave rise—in a very different direction—to the anthropoid ape family? We must admit that we have no factual evidence on which to base an answer to this question, for the fossil record of the earliest stages of hominid evolution which must presumably have preceded the stage represented by the Australopithecinae is completely blank. It is true that we have the fossil remains of many anthropoid apes that lived during the Miocene and Pliocene periods of geological time, and we know that some of these were generalised creatures which had not developed the specialised characters which are distinctive of the modern apes as we know them today.

20 MILLION YEARS OF EVOLUTION

This is particularly the case with the extinct apes whose remains have been found in such abundance as the result of the work of the British-Kenya Miocene Expedition which was begun in 1947. From the purely anatomical point of view they might conceivably have provided the basis for divergence of the two evolutionary lines—one leading to the modern apes and the other finally culminating in modern man. But this is conjecture—and must for the present remain conjecture. It is probably true to say that most anatomists who have given thought to the problem agree that the divergence must have occured at least as far back as the Miocene period—that is, a matter of twenty million years or so—on the grounds that the anatomical differences between hominids and apes could hardly have become developed in a shorter period of geological time. The fact that this is, at the most, very indirect evidence only serves to emphasise our complete lack of direct evidence on this crucial problem.

It has been my intention to give only a very general survey of the sort of fossil evidence at present available which has a bearing on the evolutionary origin of our own species. I have tried to present this evidence objectively and to emphasise that, although it allows us to draw some very interesting conclusions, it is still too scanty and fragmentary to complete the story with any degree of certainty. Indeed, even some of the rather general conclusions which I have presented to you must be accepted as no more than tentative and provisional interpretations which will require to be confirmed by the discovery of more extensive fossil material.

The need for the greatest caution in the interpretation of isolated and fragmentary remains of unusual type which are assumed to be those of early man or of his evolutionary precursors has been made apparent to all by the recent exposure of the Piltdown forgery. This will perhaps go down in the history of archaeological discovery as the most elaborate forgery of its kind ever perpetrated. Indeed it was its very elaborateness which led to the deception of so many eminent authorities for so long a time. But, almost as though it were a sort of inevitable compensatory mechanism, good may often come out of evil, and so it is in this case. For the investigation of the Piltdown forgery has led to the development and perfection of a whole battery of techniques which will not only make it virtually impossible for anyone to repeat such a deception, but which will be of the greatest use in estimating the relative antiquity of genuine fossils. These techniques include such methods as fluorine analysis, microchemical tests, X-ray spectrography, crystallographic analysis and the estimation of radioactivity. It is of particular interest to note that one or two of these tests have already confirmed the supposed antiquity of some of the isolated remains of prehistoric man, and no doubt they will in time be applied to all fossil relics whose antiquity may be in question. In this respect, therefore, the study of fossil man in the future can proceed on a much surer foundation of factual evidence and with a correspondingly lesser need for speculation.

When we look back over past ages and try to visualise for ourselves the gradual emergence of humanity from the world of living creatures, we cannot help but be impressed with the supreme difficulties that our ancestors had to overcome during every stage of their evolutionary realisation. There seems to be a tendency these days to depreciate the idea of 'struggle' in evolution, and to decry the well-known phrase 'struggle for existence'. But the process of natural selection is by no means only a passive process so far as the individual is concerned—it must surely always involve a very large element of struggle. By this I do not necessarily mean actual physical conflict between one individual and another, or between one biological group and another. I mean, rather, the constant effort and striving to overcome all the hazards and dangers of an environment which, if not actually hostile, is essentially an unfriendly one. Our early palaeolithic ancestors in Europe, for example, must have had continually to struggle against odds of almost incredible difficulty—facing from day to day all the risks and uncertainties of the most primitive methods of foraging and hunting in their search for food, defending themselves against the attacks of dangerous animals with stone weapons of only the crudest kind, contending at times with the most severe extremities of climate, and striving against all the many other vicissitudes and insecurities of their precarious existence. Yet they did win through. If Man survived the birth pangs of his own becoming in spite of all these odds, who will say that there is any crisis or danger of his own making which Man may not overcome? And, if the fate of all humanity seems to some of us now to be clouded with uncertainty, we can surely derive inspiration and courage for any trials of the future by contemplating the achievements of our forebears in the past.

Finally, let me end this lecture by completing the lines of Matthew Arnold which I started to quote earlier on:

> "Man hath all that Nature hath, but more,
> And in that *more* lie all his hopes of good."

BREEDING PLANTS FOR HUMAN NEEDS

PROF. S. C. HARLAND, F.R.S.

Man is not the only organism that wants food. Other organisms besides man want it, and will take it if they get the chance. In the earliest historical records we read of 'blight' on man's food crops, and only this year a new type of black rust with the non-committal name of 15B has caused serious damage to the special variety of Durum wheat used for making macaroni in North America. In the centre of Durum wheat production in the north-eastern part of North Dakota, attacks by the dreaded 15B rust has cut the crop by 50% during the last two years. This year the situation is even worse, and in some areas the crop has been so badly damaged that it is not worth collecting.

Likewise, in many European countries the potato crop has suffered extensively from 'late blight'—the very same disease that destroyed the potato crop in Ireland in 1846, and through famine caused so many of its inhabitants to seek their fortune elsewhere.

Less than a hundred years ago this state of affairs was regarded as natural and normal. The parasitic nature of fungi and bacteria was unknown. Blights and mildews came from Heaven and nothing could be done about them, though that shrewd observer, Theophrastus, writing more than 2000 years ago, noted that cultivated varieties of plants sometimes differed in their reaction to disease. And as early as 1850 it was recognised that the 'onion-smudge' disease could seriously attack white varieties of onion when coloured varieties grown alongside were completely unaffected. In the last few decades the study of plant disease has become a major branch of botany and a great deal is now known about all the important diseases of most economic crops.

Only occasionally can the plant pathologist provide a remedy for disease. He can recommend various chemical substances known as fungicides, of which the first was the well-known Bordeaux mixture used against the downy mildew of grapes as early as 1882, and the latest some of the new antibiotics, such as streptomycin, which are said to be effective against some plant diseases due to bacteria. Chemical remedies are expensive, and even spraying with plain water would cost money.

The best way to safeguard our crops from destructive diseases is to grow immune or resistant varieties, and this is one of the main tasks of the plant-breeder. To illustrate what he does, let us go back to 1905 and wheat. In that year Biffen of Cambridge took the wheat variety Rivet, which was known to be highly resistant to the disease known as Yellow Rust, and crossed it with another variety called Michigan Bronze which was very susceptible. He found the hybrid wheat to be as susceptible to yellow rust as the Michigan Bronze parent. In the next generation about one-quarter of the plants were resistant, and three-quarters susceptible. Resistance continued to breed true in the next and all subsequent generations. Some of the new resistant forms were much better in the quality of their flour than Rivet, and so the way was opened up to a vast improvement in the disease-resistant properties of our cultivated cereals.

Disease-resistance is inherited as are other desirable characters such as short, stiff straw, high quality, resistance to drought or frost, or a score of other characters. Disease-resistance could now be combined with these characters.

Before man came on the scene, Nature was moulding plants for millions of years. In the wild, plants have been hybridised, often inbred, and subjected to great hardships that only the fit could come through. The enormous variability that resulted was available to man before the dawn of history. For a long time he merely used what Nature provided. But soon, being observant and experimental, he began to save seeds or tubers from outstandingly superior plants, and to this simple process of selection aided by some natural hybridisation, most of our domesticated plants have arrived at their present state of relative perfection. The changes which have taken place in plants through domestication have been very far-reaching. The modern cabbage or cauliflower is far different from the wild cabbage of the sea coasts of Europe. The cultivated Japanese radish can weigh as much as 20 kilograms. The wild potatoes of the High Andes are no larger than walnuts. The wild melons of Central Asia are bitter, and of the size of tennis balls.

USING THE TECHNIQUES OF GENETICS

From the year 1900 a great change took place in our outlook. In that year the rediscovery of the work of Mendel took place. No longer was heredity considered to be a blind and capricious force. The science of genetics, the scientific study of heredity, soon began to affect plant-breeding. Men were no longer satisfied with the existing varieties of economic plants. They were very imperfect. If a variety was of good quality, its yield might be poor, or it was subject to this or that disease. A fruit or vegetable perhaps could not tolerate cold storage, or long-distance transport. So with the exacting demands of the consumer, the idea has slowly gained ground that we can use the techniques and rules of genetics to streamline and mould our cultivated plants to our very complicated needs. We can also re-explore the whole world of living plants for new products, and by using the new techniques, domesticate truly wild plants, and get from them new foods or new chemical products in greater quantities and of better quality.

How does the plant-breeder work, and what does he do? He must obviously begin with a very clear and definite object in view. Let me take as an example the potato. Let us say that a new variety of potato is required, highly resistant to eelworm. Eelworm is the parasite whose scientific name is *Heterodera rostochiensis*. The potato must also have resistance to late blight, and to several other diseases. Its yield and quality must be satisfactory and a whole lot of other requirements must be satisfied.

The first task is to have a large collection of potatoes to examine. Nearly all cultivated plants have in some part of the world a centre of variability, where large numbers of varieties are to be found, often cultivated by primitive peoples who have preserved in a very mixed state the varieties of their ancestors. It is essential to make large collections of such material, and to keep them on tap in case we get a new problem of breeding for resistance to a new disease. With the potato we are very fortunate. We know that the centre of variability of this plant is in the Andes of Peru and Bolivia, and that wild species with valuable characteristics occur as far north as Mexico. More than 1000 different varieties have been recorded from Peru and Bolivia. Some years ago a potato-collecting expedition set out from this country for Peru and Bolivia. Several hundred types were brought back. They are now preserved as a living museum at Cambridge—the Empire Potato Collection. A detailed examination of this material brought to light two Andean varieties highly resistant to eelworm. In their other characters they were of little use. They refused either to bear flowers or produce tubers except under the twelve-hour day to which they were accustomed in their native home. The task of combining this resistance with the desirable characters of our best potatoes was taken up enthusiastically by both the Dutch and ourselves, and several thousand hybrid combinations are now under examination. The task will not be easy. It may take years of work, but is worth doing. Much good potato land in this and other countries can no longer grow potatoes, and is now devoted to other crops. The problem of the eelworm is one of the most serious affecting agriculture, and so far as we know at present the only solution is in the hands of the plant-breeder.

BREEDING RESISTANT VARIETIES

So far, I have given much attention to the question of how to mitigate the ravages of plant parasites. In many instances the plant-breeder has been able to set an almost ruined industry on its feet again by the production of a resistant variety. We now have less fear about our food supply than we had fifty years ago. A period in which many of our crops were periodically devastated by disease-producing organisms has given place to a new era. Our sugar supply is safeguarded by virus-resistant sugar cane and sugar beet. In our cereal crops we have a vast range of varieties resistant to fungus rusts and smuts, though new and virulent races of rust, like 15B, appear from time to time attacking varieties hitherto thought to be immune.

I do not want to give the impression that breeding for disease-resistance is now perfectly straightforward. It is quite clear that many diseases can and certainly will be controlled by plant-breeding in the future, but basic knowledge of many fundamental problems is still lacking. We know relatively little about variability in disease-producing organisms, for often they are just as variable as their hosts. There are problems such as this: the fungus disease of tomatoes known as *Cladosporium* has been controlled several times by breeding a resistant variety. But as soon as the new variety is widely grown a completely new type of *Cladosporium* appears and brings us back to our starting-point. We do not know exactly why this happens, and we do not know why the 'late blight' fungus of the potato suddenly and virulently attacked tomatoes in 1946.

HYBRID VIGOUR

High yield has been mentioned as something at which the plant-breeder should aim. The most spectacular increase in the yield of an agricultural crop, an increase obtained solely by the application of genetical methods, is in the utilisation of hybrid maize, what the Americans call 'hybrid corn'.

In the opinion of an eminent American biologist, the exploitation of hybrid maize is "the most far-reaching development in applied biology of this quarter century". He says: "Hybrid corn may even prove, in future historical perspective, to have been one of the most important factors in saving our American culture and the European civilisation from which it was born." Certainly it is true that the increase in yield in the United States due to the employment of hybrid corn is estimated at about 800 lb. extra per acre, which means more than 900 million bushels added to the American maize crop.

The characteristic which has made hybrid corn such a major factor in food production is the phenomenon known as hybrid vigour. It is well known that hybrid plants, like mongrel dogs, are usually more vigorous than their parents. They are also more productive. Hybrid corn is produced by crossing different lines or races of maize in order to make use of this phenomenon of hybrid vigour.

When corn is artificially self-pollinated for several generations it becomes weak through inbreeding, as is the case with dogs and chickens. In the first few generations of inbreeding of this corn numerous freaks emerge. These odd types may be quite devoid of the normal green colouring matter, so they die shortly after germination. Others are dwarfs; and yet others are partly or completely sterile. But sooner or later complete uniformity is obtained. All the plants in a progeny are then of about the same reduced height and productivity, and such a progeny is known as an inbred line. Now when two inbred lines are crossed, especially if their original parents were not closely related, the resulting hybrid not only recovers all the vigour lost through inbreeding, but it is even more vigorous than before. It has other advantages: its yield may be about 25% greater than the original commercial variety, and it is so uniform in height and strength of stalk that it is much easier to reap by modern harvesting machinery.

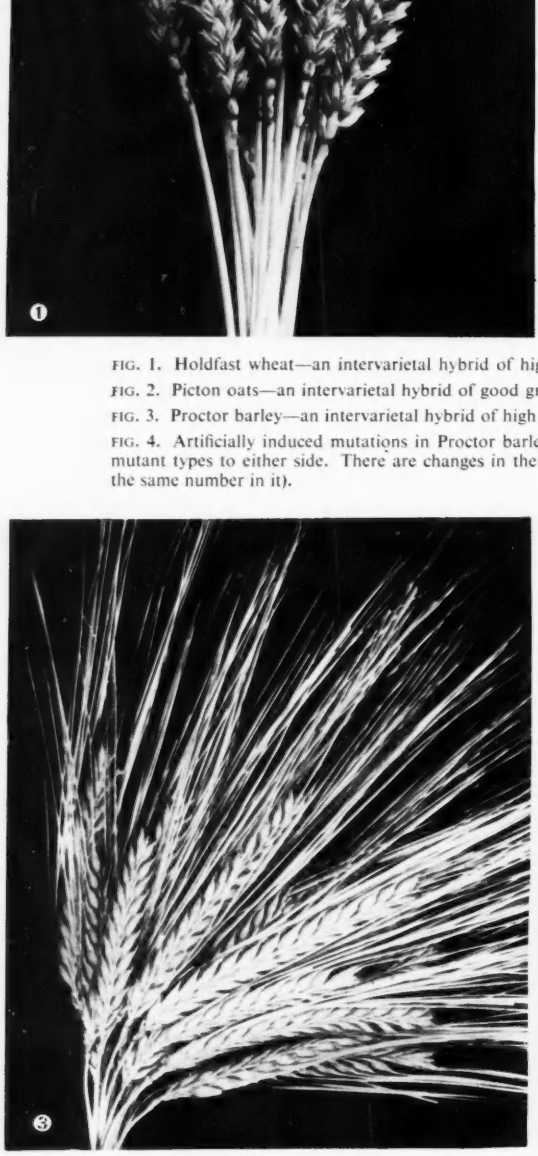
Hybrid corn is spreading to Europe and to the Tropics. At first it was thought that the standard American inbreds would serve as a starting-point for breeding hybrids for other countries, but it now appears that every country will ultimately have to make its own inbreds suited to its own climate.

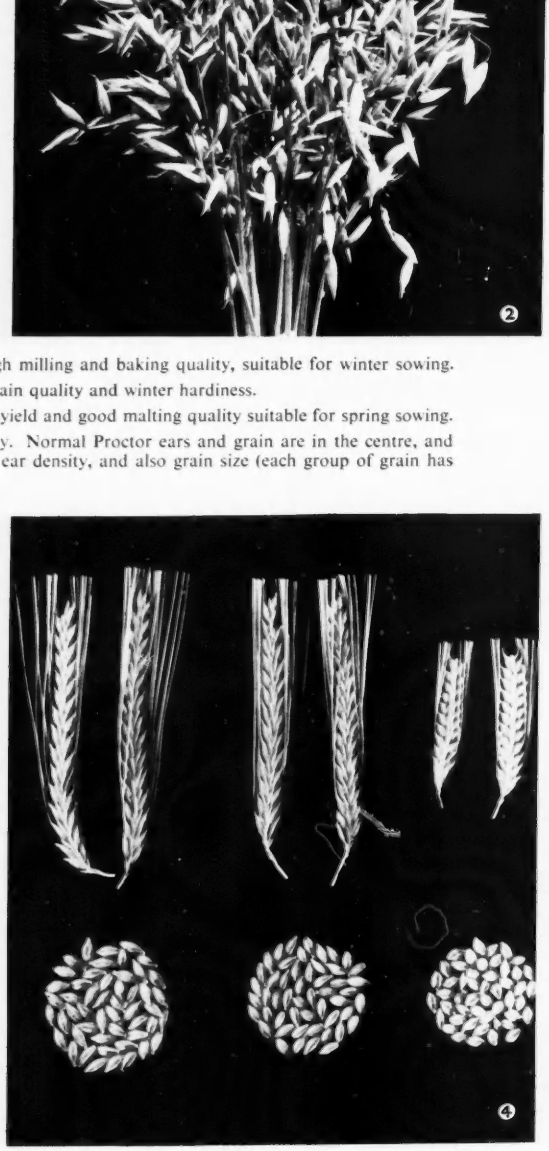
FIG. 1. Holdfast wheat—an intervarietal hybrid of high milling and baking quality, suitable for winter sowing.

FIG. 2. Picton oats—an intervarietal hybrid of good grain quality and winter hardiness.

FIG. 3. Proctor barley—an intervarietal hybrid of high yield and good malting quality suitable for spring sowing.

FIG. 4. Artificially induced mutations in Proctor barley. Normal Proctor ears and grain are in the centre, and mutant types to either side. There are changes in the ear density, and also grain size (each group of grain has the same number in it).





I might just make the point here that the development of the theory underlying the development of hybrid corn could only have taken place in an atmosphere of free inquiry, in which an immediate demand for practical and utilitarian considerations played little part. A professor at Princeton University, George Harrison Shull, was the first to study inbreeding effects in corn, and to point out the practical application of his findings. I imagine that a bureaucratic system of controlling research would have dealt very severely with a man who claimed that in order to raise the yield of corn, you first had to inbreed and reduce it by 50%!

Plant-breeders now seek to use hybrid vigour in other plants. In the last few years hybrid seeds of both tomato and onion have been put on the market. The yield is claimed to be considerably above that of existing varieties, and although hybrid seed costs about ten times as much as ordinary commercial seed, its use is rapidly spreading.

BREEDING PEDIGREE TREES

There is one group of plants in which plant-breeding has so far played a minor part, that is forest trees. After a period of wasteful and prodigal exploitation we are beginning to take our trees in hand. Millions of acres are being planted, but with rare exceptions the seed has not been produced by the plant-breeder to fulfil special needs. What are the prospects in forest-tree breeding? Well, first there is the possibility of exploiting hybrid vigour as in corn. It is known that crosses between different species, or perhaps different geographical types, have a vigour and rate of growth far surpassing their parents. Some hybrids are now being produced in quantity.

A new method of breeding was recently devised in Peru which can be applied immediately to forest trees. It is known that the offspring of a controlled cross between two selected parents has a special family resemblance, just as in families of human beings. When a large series of families out of such 'paired crosses' of trees is examined, we find some families have straighter trunks, great rapidity of growth, and high quality timber. All we have to do is to go back to the original parental pair of trees and cross them on a larger scale to obtain superior seed at one step. This method is now being applied to cocoa and coconuts. It is crude compared with the refined methods used in the breeding of other plants, but it does represent a great advance.

Another method lies in the production of giant trees. The drug called colchicine when applied to the growing points of plants has the power of paralysing cell division in such a way that all subsequent growth from this region consists of giant cells. We thus get a doubling in number of the essential cell bodies called chromosomes and a new type of giant plant is produced. These giant plants are called *tetraploids* because they have four sets of chromosomes. Now *tetraploids* are often slower in growth than *diploids*. The most rapid growth is often in the forms with three sets of chromosomes, known as *triploids*; and these can be obtained by crossing *tetraploids* and *diploids*. When these new methods are seriously applied to our forests, the future will be bright. Instead of planting millions of trees of dubious parentage, the pedigree of future plantings will be as carefully controlled as that of prize dairy cattle.

The possibilities which lie in the greatly increased rate of growth of some *triploids* has reached the sugar-beet industry. Here again, the best rate of growth is in *triploids*. By the use of *triploid* sugar beet an increase in yield of at least 15% is possible. The large-scale production of *triploids* has now been perfected, and at present, about 60% of the sugar-beet area of Denmark is now planted in this novel type of plant.

MAN-MADE VARIATIONS

Those are some of the more immediately practical methods which have come into current use as a valuable supplement to the ordinary methods used by plant-breeders. There are others which deserve mention, and here I shall be getting deeper into theoretical matters and laboratory methods. All selection depends on the natural variation present in all crop plants. Is this natural variation sufficient? Can it be increased? Sudden changes do sometimes occur spontaneously in plants which the breeders can immediately use. A giant tobacco plant once appeared with more than a hundred leaves. We call these spontaneous hereditary changes mutations, and hitherto we have had to wait for Nature to produce them. We now know that the rate of mutation can be greatly speeded up by the use of such tools as x-rays, neutrons, and radioactive elements, collectively known as mutagenic agents. The amount of variation available to the plant-breeder is thus greatly increased. Man-made variation may be more important in the future than natural variation.

The sort of mutation produced by irradiation ranges from an almost imperceptible increase in general variation to such extremely drastic changes in structure that the products can be designated as 'monsters'. Most of the changes are for the worse, but some rare ones are useful.

In Sweden the white mustard is an important oil crop. A new market variety called Primex produced from x-rayed seed gave a yield of oil about 7% greater than that of the parental strain. Primex was also more variable, and responded immediately to selection for yield of seed and oil, so that a further increase of 5% has since been obtained. In spite of repeated selection, the amount of hidden variability in the new mustard is still very great. Many mutations in other plants will raise the number of seeds per fruit and per plant, but may reduce the amount of vegetative matter. Or they may improve the yield of vegetative matter—this is important in grasses and clover—and decrease seed production.

A remarkable example of a new artificial mutation is the giant barley. Here the plant is taller, with wider and larger leaves, bigger seeds, and the straw is stiffer than

FIG. 5. Artificially induced mutations from Atle wheat. A normal Atle ear on the left, and three mutant types showing major morphological changes due to irradiation.

usual. Notwithstanding these profound changes, the mutant giant barley is reasonably good in yield of grain, and much higher than its parent in vegetative matter—leaves and straw. Here the mutation has influenced the balance between the reproductive and vegetative sides.

It often happens that the mutant is inferior to the parent strain when grown under the same conditions, but it may be better adapted to new environments and in these it may actually be better than its parent, either in yield of grain, of vegetative matter, or both. The giant barley just mentioned is, for example, adapted to a drier climate than that of most of Sweden.

Another advantage of mutants is that when a mixture of plants of mother strain and mutant strain is grown, the yield may be better than that of either strain by itself. The mutant may have a shallow and much branched root system, while that of the parent may ramify and feed at a much greater depth. It is obvious that in such a case by growing a mixture of two or more types, we can simultaneously exploit several different layers of the soil.

Mutants with short and stiff straw are frequently produced by irradiation. This, even by itself, is a character of the greatest importance. The crop is not broken down by heavy rain. This new type of straw is accompanied by another mutant which increases the ability to make use of heavy applications of nitrogenous manure, and so the yield goes up and up.

Can mutants be obtained with greater disease-resistance? Preliminary work suggests that this is possible. Some mutant barleys are less attacked by the smut disease than their parent strains, while in Carolina it has been noted that x-ray treated ground-nuts show an increased variability in their resistance to leaf-spot disease.

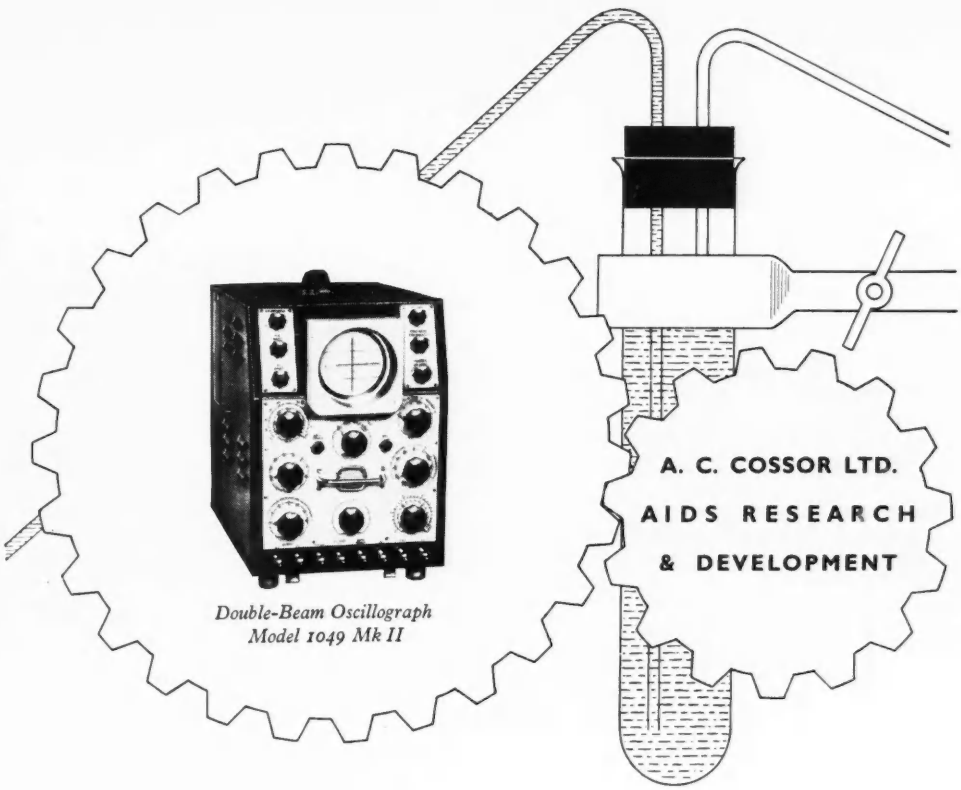
All these facts about mutants indicate great possibilities for the future It is now firmly established that by using these mutagenic agents we can induce heritable modifications which can cause an increase in grain, vegetative matter, or both of these. Further, we can alter the climatic requirements of a species and perhaps get it to grow in new regions. This is possibly the way to get soya beans and other sub-tropical plants to grow in this country.

The possibility of changing the chemistry of a species by plant-breeding may now briefly be considered. This can imply a decrease in the amount of some noxious substance, or an increase in the quality of a desirable one.

The oil-content of cotton seed has been increased by selection in Peruvian cotton from 18% to 24%, and cotton may now be looked on as a first-rate food plant. There are varieties of tobacco without nicotine, and if there are other identifiable toxic substances in tobacco it might be possible to get rid of them.

The European Lupin contains a poisonous alkaloid. Alkaloid-free types have been bred in Germany and Russia, and a new food crop with a protein content of over 40% in the seeds is now available for human consumption. The Andean Lupin will grow at an altitude of 12,000 ft., not far from the snow-line. We now have an alkaloid-free type which will provide a new source of food for the Indian population, in great tracts of country where practically nothing will grow.

These are some of the achievements of the workers who breed plants for human needs.



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THE SCENT LANGUAGE OF HONEYBEES

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Bee Department, Rothamsted Experimental Station

It is a relaxation to turn from the pressing problems of our own community life to study for awhile the social life of the honeybee, which is very interesting and quite different from our own. Only a small proportion of the two million different kinds of insects that exist today live in communities, and of these only a few share the honeybee's habit of living in a large and well organised society. We know more about the mode of life and the behaviour of the honeybee than that of any other social insect, for the obvious reason that the economic value of its honey and its wax made it worth while for man to domesticate this insect, with the result that its activities have been kept under close observation for many centuries.

As in all other social insects, the family forms the social unit, and there has been no integration above that level; never does one come across a number of families associating together to form a community in the way that happens in the case of man. Nevertheless a honeybee colony can reach a considerable size, and it may come to contain as many as seventy thousand worker bees, all of them the progeny of one fertile female, their queen. The queen lays all the eggs, and the workers carry out all the other work of the colony. The efficient functioning of this large family is clearly impossible unless its members are able to communicate with each other effectively, and recent researches have shown that taste and smell play an important role in the methods of communication used by honeybees.

BEE SCENT

Over fifty years ago—in 1902, to be exact—Frank Sladen recorded that he had noticed a distinct and somewhat pungent odour arising from a swarm of bees which he was putting into a hive. He noted, moreover, that at the same time many of the bees at the entrance of the hive were rapidly beating their wings (this action is known as 'fanning') and standing in a characteristic attitude—with the tip of the abdomen raised so as to expose a portion of the membrane that connects the fifth and sixth segments of its dorsal surface. Sladen then took several newly killed worker bees, dissected off this membrane and showed that this material was capable of attracting other bees. He thus established that the bee's scent was associated with this membrane, and proceeded to his final conclusion which was that the scent (and not the noise of the vibrating wings, as had hitherto been supposed) is the means of allurement which enables a fanning bee to attract her companions and encourage them to enter the hive.

FIG. 1. Returned foragers fanning and scenting on the alighting board of their hive.

The scent organ is exposed in other circumstances when it would be useful for a bee to attract her friends. It has been noted, for example, that bees which are collecting from a dish of strong sugar solution usually scent in this way, and the frequency of this scenting tends to be proportional to both the concentration of the syrup and the ease with which it is obtainable. As often happens when one studies other aspects of bee behaviour, one finds that there is much variation between different individuals; when one watches a number of bees collecting from the same dish, one sees some bees which do not scent even when collecting very rich syrup, whereas other individuals scent even when the syrup is much diluted. The extent to which bees expose their scent organ when they are working on flowers has not been settled; some observers have seen them perform this action, and the Indian honeybee is said to do it frequently while collecting nectar from flowers.

As one might expect, honeybees can use the scent which they give out as a guide to themselves on a return visit to a source of sugar or nectar, as well as to attract their companions. Moreover, recent experiments have shown that this scent has other surprising and important properties—the bees of each colony produce a distinctive scent, which is different from that of other colonies.

RECOGNITION OF COMPANIONS

Some experiments which shed light on the bee's ability to recognise members of its own hive have been carried out at Rothamsted. The apparatus used in these experiments is shown in Fig. 2, and it includes two small dishes which are set down in a field about 30 inches apart; each dish is surrounded by an open box which serves as a wind-shield. The box in the centre does service as a partition and also as an extra wind-shield.

Two colonies of bees, *A* and *B*, are placed fifty yards or so away from the pair of feeding dishes, and the stage is now set for our first experiment. The experimental procedure is as follows: On the first day a group of 50 bees from Colony *A* are trained to collect sugar solution from dish *a*, and the thoraces of these bees are daubed with white paint; during this day Colony *B* is not allowed to fly, and dish *b* is kept empty.

On the second day Colony *A* is not allowed to fly and

dish *a* is empty, while a group of 50 bees from Colony *B* are trained to collect sugar syrup from dish *b*, and their thoraces are marked with blue paint.

As soon as the group of bees from Colony *B* have been marked, Colony *A* is also allowed to fly. Both dishes are now filled with sugar solution. For a period all unmarked bees coming to either dish are killed and ignored, until similar numbers of the marked bees from both colonies are seen to be foraging from their respective dishes. From this time onwards all unmarked newcomers are marked with the same two colours, according to the dish which they visit, but now the daubs of paint are put on their *abdomens*, so that they can be distinguished from the guides which were marked previously.

When about a hundred newcomers have been marked in this way the experiment is stopped. At the end of that day the two colonies of bees are opened, and all the marked bees inside them are killed and recorded. It is then found that most of the newcomers from Colony *A* have visited dish *a*, at which their hive companions foraged, whereas most of those from Colony *B* went to dish *b*.

This experiment, which we have repeated at Rothamsted many times, has demonstrated that when hivemates and bees from another colony are foraging in similar numbers from nearby dishes which contain exactly the same food supply, the hivemates are much more attractive than the strange bees, so that one must conclude that the hivemates are recognised in some way.

In another experiment using the same apparatus, bees from one colony were trained to dish *a*, and no bees at all were trained to dish *b*. Both dishes were then supplied with sugar syrup. During the next two hours 45 recruits went to dish *a*, but only 3 visited dish *b*. Dishes *a* and *b* were then exchanged, and after some initial confusion the trained bees now proceeded to visit dish *b*—in other words, a new dish on the old site. During the next fifteen minutes 9 more recruits came along, and all but one of these went to dish *a*, which the trained bees were no longer visiting. Thus the recruits were not being attracted by either the sight or sound of the trained bees, *but by something pertaining to the dish which they had previously visited.* The lure could only be bee scent. Moreover, as dishes frequented by hivemates are more attractive than dishes frequented by strange bees, the bee scents which come from bees of different colonies must be different.

These simple experiments demonstrate that honeybees can recognise their companions because they possess a distinctive smell, which is different from that of the honeybees of another colony.

THE ORIGIN OF THE DISTINCTIVE ODOURS

This phenomenon of recognition offered another fascinating problem for investigation; what is the mechanism whereby honeybees come to possess these distinctive odours? Further experiments showed that these odours were not inherited, and these were followed by a series of experiments which proved that they derived from the food supplies which had been eaten by the bees.

These experiments were of two kinds. In the first set of experiments, colonies were divided into portions; the different portions of each colony were fed with different

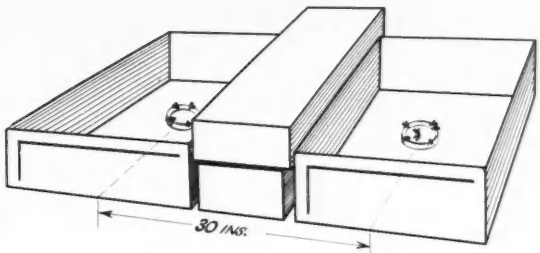

FIG. 2. Apparatus for studying the attraction of companions. The two glass dishes are surrounded by a brood chamber and separated by a nucleus box.

kinds of honey, and the bees in the differently fed portions were shown to possess different odours. In the other set of experiments, all the food supplies were removed from several colonies; all these hives were then taken to a Welsh moor, where they could obtain nectar from only a single species of flower, namely ling (*Calluna*); all these different colonies, after feeding on the same diet, came to possess the same odour.

FOOD SHARING

These results in turn suggested still more interesting problems. It is easy to understand how all the bees in a colony acquire the same scent when the food supply is homogeneous, as in the instance just cited where all the bees fed on the same kind of nectar, but it is not easy to understand how they all produce the same scent when a mixture made up of many different kinds of nectar is taken into the hive. Another set of experiments answered this question, by demonstrating that the mixture of foods taken into any hive is evenly shared among all the bees in that hive. For these experiments, radioactive sugar prepared by the Radiochemical Centre at Amersham was used. The experimental procedure for these experiments is quite simple. A marked bee is trained to collect sugar solution from a small glass tube, and when radioactive sugar is substituted the bee proceeds to collect the radioactive syrup quite happily. The bee now carrying its fill of radioactive sugar returns to the hive, and what happens to that 'labelled' sugar after it enters the hive can be followed with comparative ease. Every bee that receives some of the radioactive sugar can be spotted by means of a Geiger counter. By collecting a sample of bees from the hive one can discover what proportion of the colony has acquired some of the radioactive sugar, and by taking periodical samples it becomes possible to find out the rate at which the sugar is being distributed through the colony. Some striking results have already been obtained in this way, and published. Other experiments, which promise to give even more exciting results, are still in progress. We now know that one stomachful of radioactive sugar can be shared out among almost all the bees in a large colony. The experiments with radioactive sugar have also indicated that this sharing is a random affair; the sugar is passed on irrespective of the recipient's age or of its occupation.

These facts about the food-sharing habit help to explain

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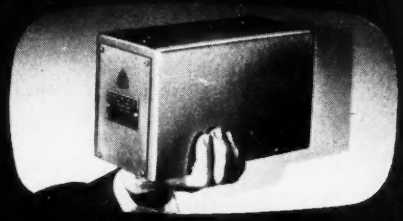

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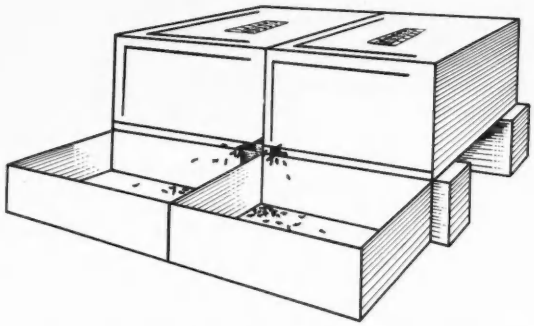

FIG. 3. Community defence. Two hives are placed together, with their very small entrances only 2 inches apart. Empty boxes in front of the hives receive any dead or injured bees.

the results of the field experiments on bees' scent. The floral nectars and pollens brought into any colony contain the different and distinctive scents of the different flowers from which they come. When those foods have been digested, derivatives of those chemicals which account for the various floral scents accumulate in the scent glands of the bees, and because each bee in that colony has received a more or less equal share of each and every item of food reaching the hive, each bee will produce a similar scent.

THE DIFFERENT FOOD SUPPLIES OF NEIGHBOURING COLONIES

The food-sharing experiments showed how the bees in any one colony come to share the same foods, and so to produce the same odour, but this is but one of the conditions necessary before the food-derived odours will enable the bees to distinguish between the scent of their companions and that of the honeybees of other colonies.

Of equal importance, the bees of different colonies must obtain different mixtures of foods. Why should this happen, even if the colonies happen to be living in the same apiary?

In each colony many thousands of bees are collecting food supplies, and if these bees foraged quite independently neighbouring colonies would obtain almost identical mixtures. However, the well-known discoveries of Prof. Karl von Frisch have explained why this does not happen. He proved that successful foragers, returning to their hive, give samples of their booty to their hivemates so that they may know what scented food they should search for, and immediately afterwards the foragers perform a dance which tells their hivemates the direction and distance away from the hive to the crop.

Von Frisch's students have shown that this message system is so widespread that bees seldom need to find new crops for themselves; nearly all of them collect from crops which they have been told about. In consequence the colony, not the individual bee, becomes the foraging unit, and neighbouring colonies usually gather quite different proportions of the various kinds of nectar and pollen which are available to them.

Thus, by food sharing between forager and recruit different colonies collect different food supplies, and by food sharing between all the bees of each colony those supplies are so evenly distributed that the bees of each colony produce the distinctive odour which enables them to recognise one another.

THE USE OF THE DISTINCTIVE ODOURS

In nature one does not expect complex mechanisms to be preserved unless they are of some advantage to the animals which possess them, so it is legitimate to ask what use the honeybee community makes of its distinctive odour. What advantage, if any, does the honeybee gain from its ability to recognise companions? If one bee meets another bee on a flower, it is doubtful whether either would obtain any advantage from being able to recognise the other as a hivemate; it seems highly improbable that the distinctive odours have evolved and been perpetuated because they were of use in this situation.

But there is one circumstance in which the recognition of hivemates is of great value to bees. At those times of the year when there are insufficient flowers to provide all the bees with food, they often try to steal the honey which is stored away in the honeycombs of other colonies. In such conditions the ability to recognise hivemates and to distinguish them from all other honeybees will enable the colony to defend itself against attempts at robbery by members of other colonies.

However, the honeybee community does not defend itself by attacking every invader that does not possess the

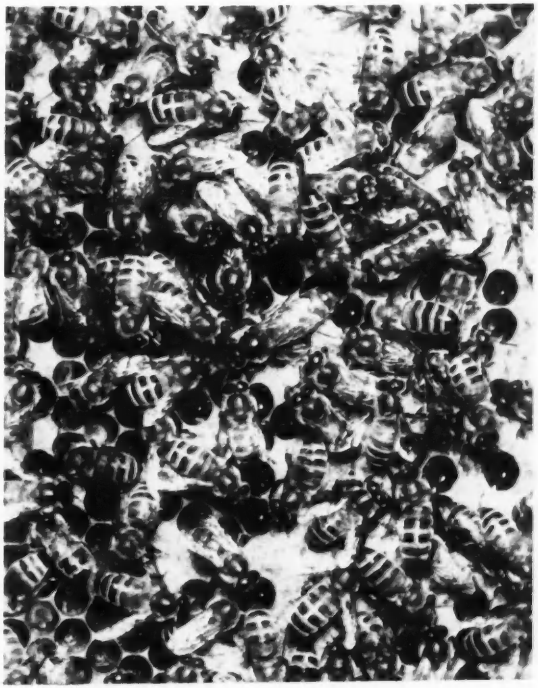

FIG. 4. A queen bee with her attendant workers.

FIG. 5. Food being passed from one bee to another. Food sharing is the system of communication which welds the honeybee colony into a social unit.

community odour. Strangers are only attacked in certain circumstances. In order to investigate those circumstances, two colonies of differently coloured bees were placed close together, with their entrances only two inches apart, so that bees often went into the wrong colony by mistake (Fig. 3). When good supplies of sugar were available, the intruders were allowed to enter the strange colony, but when sugar was short the strangers were attacked and thrown out, often being killed in the process.

In further experiments, bees from one of the two colonies were trained to visit dishes filled with sugar solution, but no sugar was made available to bees from the other colony. When this happened I found that the colony whose foragers were collecting syrup would tolerate strangers from the other colony, although these intruders went into it without food; on the other hand, the colony that was not foraging attacked strangers even if they were carrying full loads of rich sugar solution. This experiment showed that the chance of successful entry was determined by the behaviour of the bees in the colony which the intruder tried to enter. The fact that robbing occurs when foragers are not otherwise employed and that colonies are mostly guarded by unemployed foragers makes this result understandable.

The production of a common and distinctive odour, which enables the colony to defend itself against members of other honeybee communities, is a very important consequence of the habit of food sharing, and it must have provided an important stimulus for the evolution of this habit—better sharing means better defence, and so a greater likelihood that the community will be able to survive and to perpetuate its kind.

THE ROLE OF FOOD SHARING IN COLONY ORGANISATION

We have seen how food sharing is associated with the production of distinctive odours, and so with the recognition of companions and with the defence of the community. It can thus be appreciated that food sharing serves, indirectly, as a means of communication between the members of the colony. This is one of the most interesting aspects of food sharing, but this habit has other uses connected with communication, which are equally important.

It plays the key role in the system of communication which enables the new forager to learn about suitable crops, in that the new recruits always receive a sample of the crop the colony is working; their first flight becomes a search for a crop with a similar scent. The food-sharing habit enables the worker bees in the colony to be appraised of the presence of their queen; a substance derived from her body is conveyed from bee to bee in the shared food, and in the event of any deficiency in that substance they take steps to rear another queen.

In addition, it probably helps to ensure an effective division of labour in the colony, which has to be so integrated that a suitable proportion of the worker population carries out each of the various tasks necessary for the maintenance of the colony. Evidence of this attribute of food sharing is now accumulating. There are, for example, the observations of Dr. Martin Lindauer, who studied how the activities of bees engaged in collecting water are regulated to suit the colony's need for water; when much water is required, the collectors are able to give up their loads as soon as they reach the hive, but when the need diminishes they cannot dispose of their load so quickly, and then they do not go out of the hive to collect any more.

More and more facts are being accumulated which support the view that food sharing is the *basis* of communication in the honeybee colony, and since communication is the essence of social life it is to be expected that food sharing will receive more and more attention from the research workers who study the life of the honeybee.

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THE EXPLORATION OF CLOUDS BY RADAR

B. J. MASON, M.Sc.

The author directs the researches of the cloud physics laboratory in the department of meteorology, Imperial College, London; these are mainly concerned with the fundamental physics of clouds and rain. Experimental and theoretical investigations are in progress on atmospheric nuclei, the condensation, supercooling and crystallisation of water, the growth of ice crystals, the mechanisms of rain formation, radar studies of clouds, thunderstorm electricity and the design and evaluation of rain-making experiments.

The advent of short-wave radar provided the meteorologist and, in particular, the cloud physicist with a powerful new tool. The fact that clouds may reflect sufficient of the energy in the incident radar beam to be detectable by a sensitive radar receiver many miles distant enables him to study these clouds in the comfort of the laboratory. A small proportion of the incident energy is scattered back to the receiver-transmitter by the particles that compose the cloud, the actual fraction being determined by the size and concentration of the particles and on the radar wavelength. The magnitude of the echo depends on a number of factors, including the concentration of particles in the cloud, the radar wavelength, and the range of the cloud. This reflected signal is detected by the receiver, greatly amplified, and displayed on the screen of a cathode-ray tube to produce the radar 'echo' from the cloud.

Most present-day radars work on wavelengths of either 3 cm. or 10 cm.; these are capable of detecting a cloud only if it contains large particles, i.e. raindrops, snowflakes, ice pellets or hailstones (collectively known as precipitation elements). The echoes returned from non-precipitating clouds which consist of tiny water droplets or ice crystals having diameters of order 10 μ (1 μ is one-thousandth of a millimetre) are much too weak to be detected above the noise in the radar receiver. These clouds can, however, be detected at radar wavelength below 1 cm. and the very recent introduction of millimetric radar promises exciting new possibilities in the detection and study of clouds. These very short waves are, however, very strongly attenuated by rain, so that it will still be necessary to use centimetric radar for studying the precipitating clouds with which this article is mainly concerned.

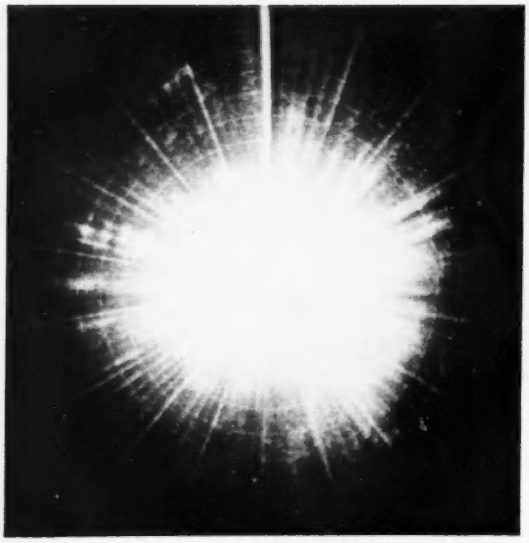
For the most part, radar has been used to locate the position of storms in space up to distances of 100 miles or more, and to follow their distribution and movement. Such information has obvious practical application to the short-range forecasting of rain, the development of thunderstorms and the probable tracks of hurricanes. More detailed study of the echo allows one to deduce a good deal about the structure, growth and development of the storm, and the constitution of the cloud. Thus, radar, particularly when used in conjunction with instrumented aircraft and supplemented by careful visual observations, has proved an invaluable research tool to the cloud physicist.

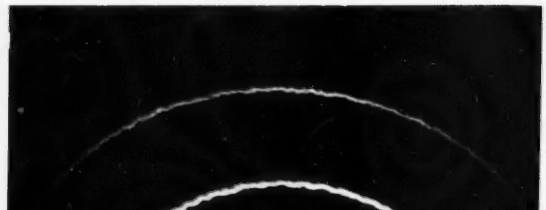
PRESENTATION OF RADAR INFORMATION

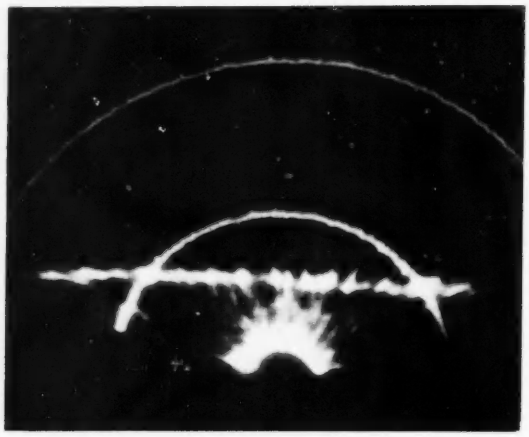
The kind of information which can be obtained from the radar exploration of clouds includes the location of the storm in space, the general shape, extent and movement of the precipitation areas, and the distribution and growth of the precipitation elements within the storm as revealed by variation of the echo intensity. Presentation of these data requires the use of more than one type of cathode-ray tube display.

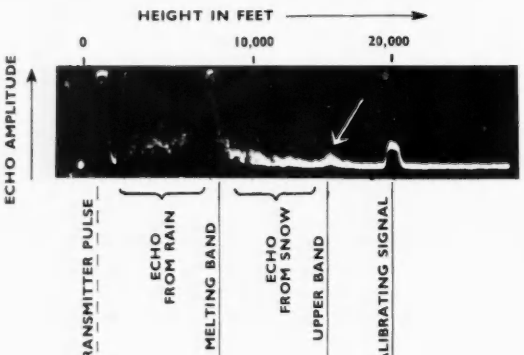
That most suited to featuring the distribution of storms is the Plan Position Indicator (PPI) which gives a projection of the radar echoes received from all points of the compass on a horizontal plane, that is a circular map centred at the radar set (Figs. 1, 6, 9). The range of the echo is measured radially from the centre of the display with reference to the range-marker rings which in Fig. 6 are spaced at intervals of five miles. The transmitter/receiver aerial rotates continuously in a horizontal plane and the radial time-base of the cathode-ray tube rotates in synchronism with it. The use of a long afterglow screen ensures that an echo persists for at least as long as the period of revolution of the aerial, so that a complete picture of the echo distribution is always presented. The PPI display thus provides the range and bearing of a storm relative to the radar set but no information concerning its height.

To study the vertical development of a cloud on a given bearing, a Range-Height Indicator (RHI) is used. The aerial is generally fixed in the azimuthal plane and scans in the vertical plane; the time base moves in synchronism with the tilt of the aerial and is brightened by the echo at a distance from the origin corresponding to the range. Thus, one obtains a plot of the slant range and the angle of elevation of the target which is, in effect, a plot of slant range versus height. Most RHI radars suffer from the disadvantage that the tilt of the aerial is limited to, say, 30°, so that the upper regions of nearby storms cannot be seen. This kind of presentation is shown in Figs. 5, 7, 8. This limitation can be overcome by using an aerial system which sweeps from horizon to horizon through the zenith to give a vertical cross-section of the atmosphere on a fixed bearing. Such a system is in operation in the author's London laboratory and is most useful and convenient for studying the structure and development of clouds (see Figs. 2, 4, 10, 11). Difficulties arise, however, in interpreting the structure of a thunderstorm passing nearly vertically









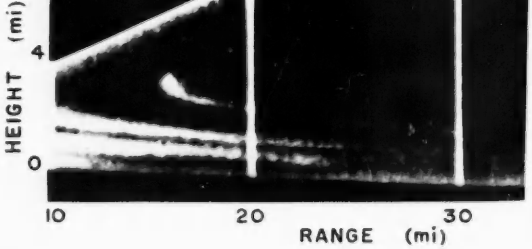


FIG. 1 (*top left*). A PPI display of a warm front on a 10 cm. radar. The radial 'spokes' in the echo are due to the screening effect of trees near the radar. The range circles are 5 miles apart.
(*By courtesy of the Director, Meteorological Office*)

FIG. 2 (*centre*). A picture of warm front precipitation showing the melting band taken on a RHI display with the aerial sweeping in a vertical plane through the zenith. Range circles are at intervals of 2 miles. Wavelength 3 cm.

FIG. 3 (*bottom left*). An A-scope presentation of a warm front; the aerial points vertically upwards to give a plot of echo amplitude against height. The picture shows a well-defined melting band and a weak upper band (shown by arrow). Wavelength 3 cm.
(*By courtesy of Dr. I. C. Browne, Cavendish Laboratory, Cambridge*)

FIG. 4 (*top right*). A diffuse radar upper band above a very weak melting band on a RHI display. Wavelength 3 cm.

FIG. 5 (*bottom right*). An upper band shown as a sloping snow trail originating in a compact generating cell at a height of 16,000 feet.
(*By courtesy of Dr. J. S. Marshall, McGill University, Montreal*)

overhead because attenuation of the echo in the heavy rain causes distortion of the picture. But these are being resolved by working in close co-operation with the Meteorological Office which operates a powerful set with PPI and restricted RHI scans at Dunstable; they are able to examine a storm over London from a distance of thirty miles and by taking photographs of the radar echoes from the same storm at both places simultaneously, a more complete picture of its vertical development may be obtained.

On PPI and RHI displays some indication of the strength of the echo is provided by the brightness of the spot on the screen, but no simple relationship exists between the two. Quantitative information is more easily obtained from a display in which the amplitude of the signal is plotted against the slant range or, if the aerial is pointed vertically upwards, the height of the target. This type of presentation, called an A-scope Indicator, is illustrated in Figs. 3 and 12. The variation of echo intensity with height in the cloud is determined by the nature, concentration, size and shape of the precipitation elements at different levels: it therefore affords important clues on the nature of the precipitation processes and on the growth of the precipitation elements.

In order to obtain a complete picture of the structure and development of clouds as revealed by radar, one requires all three types of display described above. A single set possessing all these facilities is not available in this country, but one such, working on 3·2 cm., is now in production in the United States.

RADAR ECHOES FROM DIFFERENT WEATHER SYSTEMS

From a study of radar displays in various kinds of weather it has become clear that different cloud systems associated with different weather situations are characterised by markedly different radar echoes. Thus on a PPI display the echo received from a cold front is very different from that associated with a warm front, while the echoes from frontal cloud systems are very different from those received from isolated showers and thunderstorms.

A typical PPI picture of a cold front is shown in Fig. 6 as a long and generally very narrow band of echo which is rarely continuous but composed of a number of small cores of echo of high intensity. When seen in vertical section on the RHI scope (Fig. 7) the cellular structure is again in evidence, the cores of high intensity now being revealed as vertical columns of echo. These are produced by the cumulo-nimbus clouds embedded in the frontal cloud system and are regions of strong vertical currents, strong turbulence and heavy precipitation.

The typical PPI picture of the precipitation associated with an active warm front (Fig. 1) is one of widespread and diffuse echoes with no clearly marked boundaries. The whole picture when compared with that of a cold front suggests a much more uniform rate of rainfall over a much larger area. In vertical cross-section the warm-front echoes have a very characteristic structure (Fig. 2). In almost every case a narrow band of intense echo appears at a height corresponding to the position of the 0°C isotherm and is known as the 'bright band' or the 'melting band' since it is associated with the melting of snowflakes.

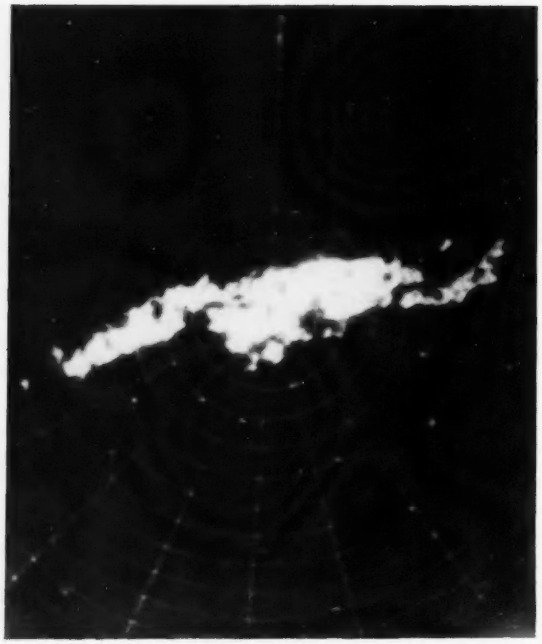
Mention has already been made of the tall, columnar echoes received from cumulo-nimbus clouds associated with cold fronts. Isolated showers and thunderstorms produce similar columnar echoes on the RHI display (Figs. 8, 10, 11) which, on occasion, may extend up to 40,000 ft. in England, and to even greater altitudes in warmer climates. Radar pictures reveal that a thunderstorm often exhibits more than one region of high echo intensity, these individual cells having horizontal dimensions of a few miles. Large and rapid fluctuations in intensity are characteristic of the echoes received from showers and thunderstorms.

Having described the general characteristics of the precipitation echoes from different cloud systems, we shall now consider them in a little more detail and relate the radar information to the physical processes at work.

THE STRUCTURE OF WARM-FRONT PRECIPITATION

The radar echoes received from widespread, steady precipitation normally associated with warm fronts and depressions lend themselves more readily to quantitative study than those from shower clouds where conditions are changing very rapidly and interpretation becomes more difficult. Typical photographs of the RHI and A-scope displays of warm-front precipitation are shown in Figs. 2 and 3. We have already mentioned the intense melting band which separates a relatively steady echo obtained from the snow above from a rapidly fluctuating echo of rather greater intensity from the rain below. The appearance of the melting band which was forecast by the theoretical calculations made by Ryde in 1946 can be explained qualitatively as follows.

Above the 0°C level the scattering particles are snow crystals and snowflakes, growth and aggregation of which cause the echo intensity to increase with decreasing height. As the snowflakes fall through the 0°C level they start to melt. Now a water particle reflects the electromagnetic energy more effectively than an ice particle of equal volume because at these very high radar frequencies, the dielectric constant of water is much greater than that of ice. Thus melting of the snowflakes will be accompanied by an increase in the echo intensity by at least a factor of five, but because the scattering cross-section of the wet disc-like flakes is greater than that of spheres of the same volume, and also because they tend to aggregate during melting, the melting band echo may be enhanced by a further factor of four or more. When the snowflakes have completely melted, they collapse to form spherical raindrops having considerably larger fall-speeds and correspondingly smaller spatial concentrations than the flakes, and also smaller scattering cross-sections. On both accounts, just below the level where complete melting occurs, the echo intensity shows a sharp decrease, with the result that a



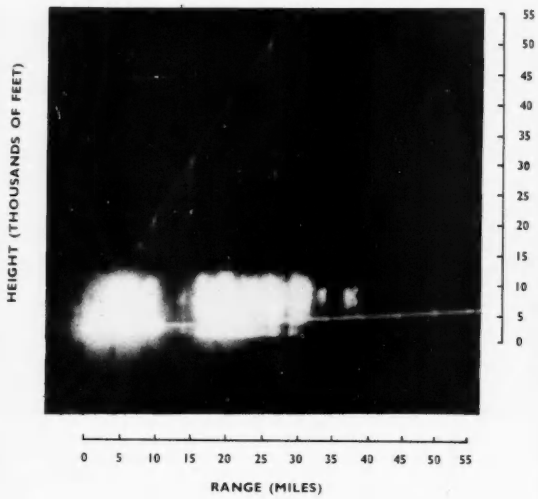


FIG. 6 (*top left*). A PPI display of a cold front showing cores of high echo intensity. The range circles are 5 miles apart.

(*By courtesy of the Director, Meteorological Office*)

FIG. 7 (*top right*). A cold front presented on an RHI scope. The front is not very active as the echo tops are below 10,000 ft., but the individual cells are particularly well defined. The height markers (vertical scale) are at intervals of 5000 ft. and the range markers are 5 miles apart.

(*By courtesy of the Director, Meteorological Office*)

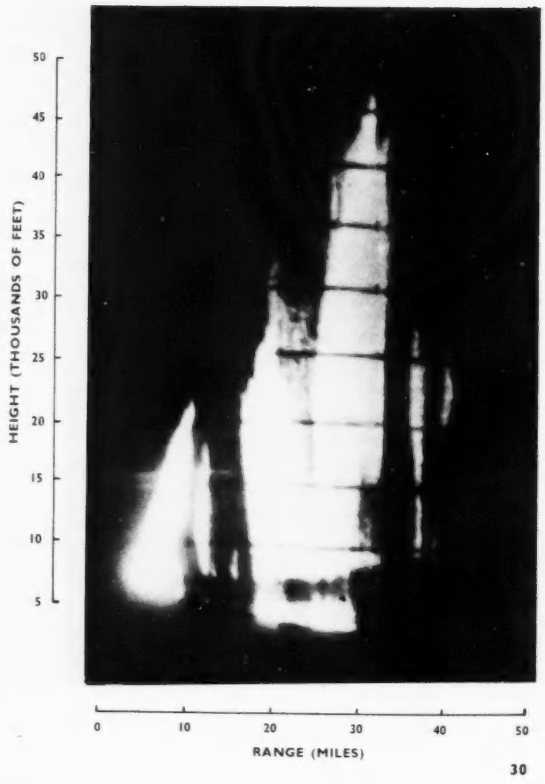
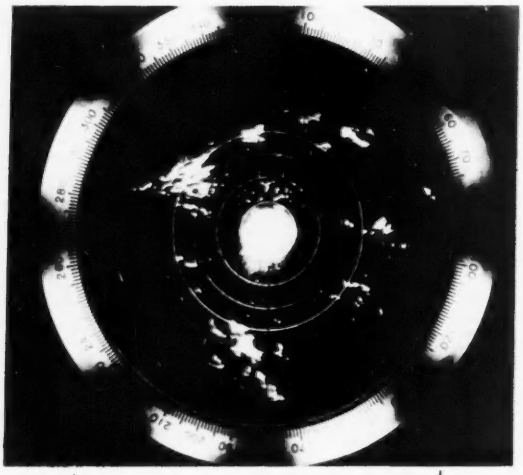
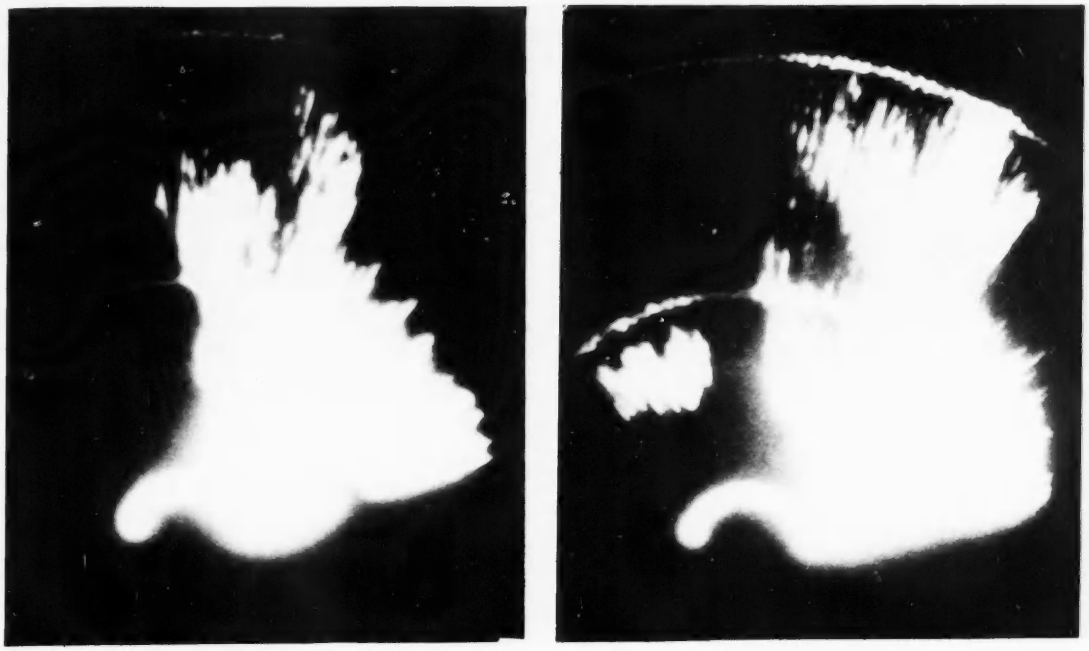


FIG. 8 (*bottom left*). An echo from a very large thunderstorm located just west of London on May 12, 1954. Two large cells compose the main echo, the top of which extended to a height of 42,000 ft. This photograph was taken on a RHI display at Dunstable.

(*By courtesy of the Director, Meteorological Office*)

FIG. 9 (*bottom right*). Showers and thunderstorms on a PPI display. Range markers at intervals of 25 miles.





FIGS. 10 and 11. These two photographs showing vertical cross-sections through a thunderstorm occurring over London on May 12, 1954, were taken six minutes apart. For further details see text.

narrow band of enhanced echo shows up between this level and the 0°C isotherm.

The formation of this melting band which is only about 500 ft. deep, and the main features of the echo from a warm frontal system can thus be explained qualitatively in terms of the growth and aggregation of ice crystals to form snowflakes, the aggregation and melting of these latter to form raindrops; these arguments can also be placed on a fairly satisfactory quantitative basis. Moreover, the presence of the melting band is a certain indication that the rain is being produced by the melting of snowflakes and therefore initiated by the appearance of ice crystals in the upper regions of the cloud—in other words, the radar picture in this case immediately indicates the nature of the precipitation process.

On some occasions strong echoes appear above the melting band, descend and merge with it; these have been termed radar 'upper bands'. They show up in a very striking manner on a RHI display (Figs. 4, 5) and can often be seen in cold-frontal conditions and less frequently in warm-front precipitation. They may appear several thousand feet above the 0°C level, occasionally remain stationary, but generally fall towards the melting band with a velocity of several feet per second. The origin and mode of formation of these 'upper bands' has been the subject of considerable argument, but evidence has recently accumulated which suggests that in most, but not necessarily all cases, they are produced by a slanting stream of snow particles originating from a localised region in the cloud and which drift horizontally through the radar beam. The slant of these precipitation streaks could be produced by an increase of wind with height; as the particles fall, they lag behind the region where they are formed, because their horizontal speed is always that of the level in question. On this picture, the measured rate of fall of an upper band is the rate of descent of the point at which the curved precipitation streak is intercepted by the radar beam.

THE THUNDERSTORM ON THE RADAR SCREEN

We have already described how the radar echo from a thunderstorm is seen to consist of one or more identifiable units or *cells*. Simultaneous exploration with aircraft has revealed that these are localised regions of pronounced vertical velocity, strong turbulence, heavy precipitation and intense lightning activity. The life of a given cell, measured from the time of the initial radar echo to the cessation of precipitation, occupies about one hour, but the really active stage may last for only twenty to thirty minutes. The initial echo is generally small compared with the dimensions of the visible cloud but it soon expands rapidly in all directions with a speed of several feet per second and may assume linear dimensions of several miles. Rain may be expected to fall

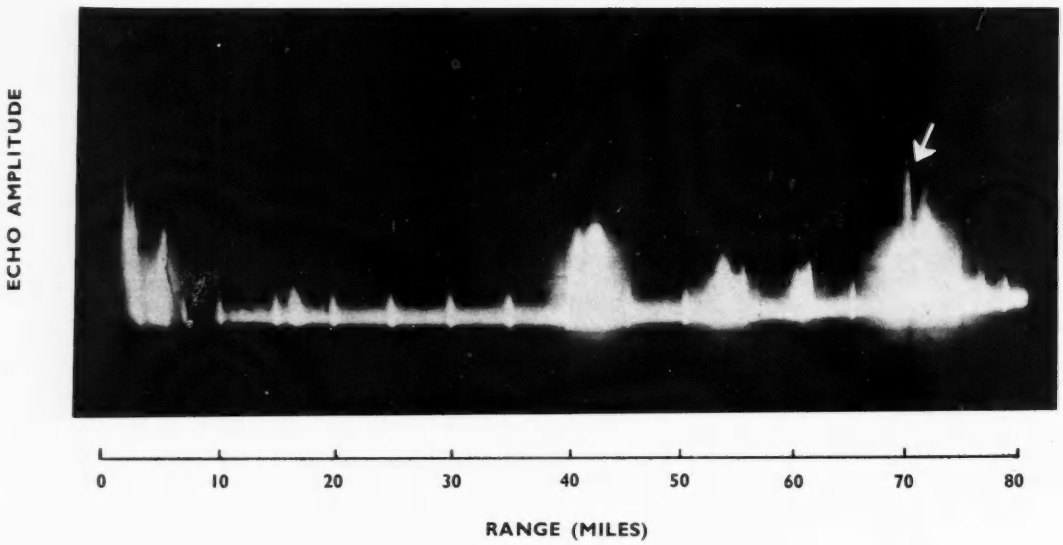


FIG. 12. An A-scope photograph showing echoes from thunderstorms and a transient echo from a lightning flash at a range of 69½ miles (see arrow). Range markers at 5-mile intervals.
(*By courtesy of the Director, Meteorological Office*)

from the cloud base about ten minutes after the appearance of the initial echo.

A study of the distribution of intensity in an echo and its changes with time provides information on the structure and development of the precipitation pattern in the cloud. The amplitude of the returned signal is roughly proportional to the mass of precipitation per unit volume. By reducing the gain of the receiver in calibrated steps, one can obtain contours of the precipitation density which may vary by as much as a factor of 100 over horizontal distances of one mile. Such patterns constructed for successive intervals of time reveal the development and changes in structure of the storm. The detailed pattern of a shower may change rapidly with time and sometimes alters completely within five minutes.

Figs. 10 and 11 show two photographs taken six minutes apart of radar echoes from a thunderstorm nearly overhead in London on May 12, 1954, with a new echo appearing on the left of Fig. 11. The first lightning flash occurred at the time of the second picture, when the main echo was more than two miles across and about 25,000 ft. in height. Fig. 8 shows the radar echo observed at Dunstable of a storm occurring at about the same time to the west of London. In this case the echo top reached 42,000 ft., the horizontal dimensions exceeding five miles.

The temperature at which the first radar echo appears is strongly indicative of the mechanism responsible for the release of precipitation. If the initial echo is situated wholly below the 0°C isotherm, where the temperatures are above freezing, one may infer that the first precipitation elements did not originate from ice crystals but were produced by the coalescence of water drops.

Traverses through cumulo-nimbus clouds by aircraft equipped with accelerometers show that the majority of strong turbulent gusts (bumps) occur within the echo-producing regions of the cloud. In particular, a well-defined echo edge, which often marks the boundary between two adjacent regions of very different vertical velocities, is associated with a zone of strong turbulence. Such correlations between the scale and intensity of the turbulence and certain characteristics of the radar echo are important in that they offer possibilities of avoiding centres of severe turbulence by aircraft fitted with radar.

DETECTION OF LIGHTNING BY RADAR

Strong transient echoes associated with lightning flashes are sometimes observed on the radar screen. They are most easily seen on the A-scope where they appear as strong, well-defined signals of a few milliseconds duration (see Fig. 12). The lightning echo is produced by the reflection of radar energy from the ionised column created by the flash. A study of the space and time intervals between the lightning echoes, their time of build-up and decay, may reveal a good deal about the distribution of electric charge in thunderstorms.

USE OF RADAR IN CLOUD-SEEDING EXPERIMENTS

Radar has an important role to play in the execution and evaluation of rain-making experiments. Already it has proved invaluable in the selection of suitable cumulus clouds to be seeded from aircraft by indicating those which are already in the early stages of natural precipitation, in studying the developments which may

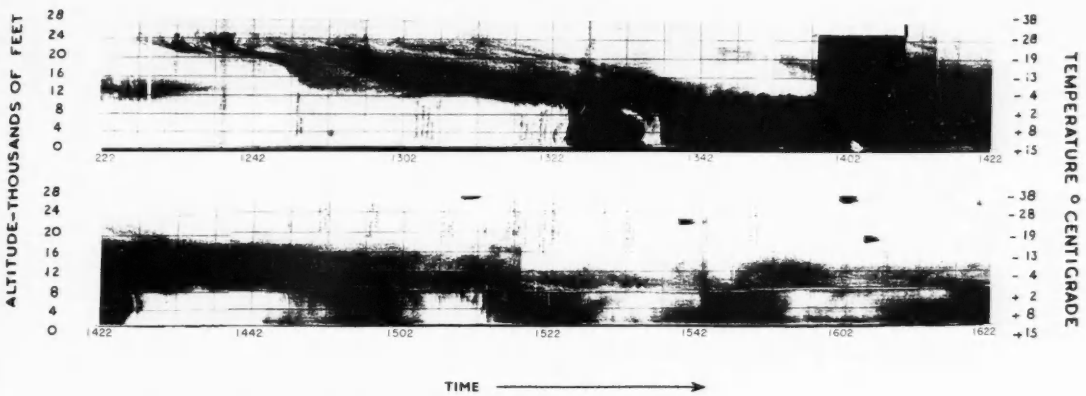


FIG. 13. An altitude-line record of clouds passing over a 1·25-cm. radar near Boston, Mass. For details see text. *(By courtesy of Mr. D. Atlas, Air Force Research Centre, Cambridge, Mass.)*

follow seeding and in comparing these with changes which occur in neighbouring non-seeded clouds.

High-power ground radar sets will facilitate the control of large-scale ground-seeding operations. Not only can it be used for following the progress of storms into the target area but also to study their subsequent development after seeding and the resulting rainfall pattern over a large area.

MEASUREMENT OF RAINFALL

The possibilities of measuring the intensity and distribution of rainfall over an area of several thousand square miles with a single radar set are worthy of careful consideration, because the inherent advantages of such a method compared with a network of rain-gauges giving records at only a series of points are obvious. The accuracy of the radar method will depend on whether there is a unique relationship between the echo intensity and the rate of rainfall, on whether the absolute intensity of the signal can be measured with sufficient accuracy, and on the stability of the transmitter power and receiver sensitivity.

Unfortunately, no unique relation exists between echo intensity and rate of rainfall, because the former is determined by the size distribution of the raindrops and this may vary appreciably in different rains of the same intensity. It seems that rain of the same general type at a given latitude may be represented by a general relation which may be applied on most occasions with an accuracy of 20% or 30%, but the same relation will almost certainly not be valid for rain of different type, particularly if this is produced by a different physical process. A further complication arises in that the drop-size distribution may change appreciably on its journey towards the ground, so that considerable errors may arise in correlating the echo intensity aloft with the rate of rainfall measured at the ground. To these inherent difficulties must be added the uncertainty involved in measuring the intensity of the radar echo, which with present radars cannot be reduced below about 30%. This all suggests that even if we work on wavelengths at which attenuation of the radar beam is not serious, we shall not be able to estimate the rainfall to better than a factor of two.

DETECTION OF NON-PRECIPITATING CLOUDS

As has been mentioned already, non-precipitating clouds may be detected by radar working on the millimetre wave-band. Equipments working on wavelengths of 8·6 mm. and 12·5 mm. have been developed in the United States and have been used largely for determining the heights of the bases and tops of cloud layers. The beam is directed vertically upwards and a continuous display of the cloud pattern is obtained by feeding the echo signal into a facsimile recorder, the paper of which moves at constant speed to give a plot of the altitude of the cloud echoes versus time, i.e. a vertical cross-section of the clouds as they pass over the set. A very interesting record, taken at the Air Force Research Centre, Boston, Mass., is shown in Fig. 13 with sloping ice crystal streamers being generated at about 24,000 ft. (between 1230 and 1240 hrs.) and falling to form an alto-stratus cloud deck. The low vertical echo beginning at 1324 hrs. represents the beginning of light rain. A very sharply defined melting band is noticeable just below 8000 ft. after 1450 hrs.

To sum up, there can be no doubt that radar has played a valuable part in the recent progress which has been made in our knowledge of the structure and behaviour of clouds. But the time is near when, in order to make much further progress, the cloud physicist will need to be supplied with equipment of higher performance and a wider range of facilities than is available at present. One feels that if the obsolete military equipment now in use, and which is inadequate for accurate quantitative work, could be replaced by sets designed specifically for meteorological research, the potentialities of radar as a tool in atmospheric physics could be much more fully exploited.

NEW X-RAY MACHINES FOR THERAPY

C. L. BOLTZ, B.Sc.

X-rays of sufficient power and duration destroy living tissue. This has been known for a long time and is the basis of the radiotherapy of cancer. The mechanism of the destruction is so far unknown.

These facts have created a demand for x-rays of high energy, conveniently expressed in terms of million-electron-volts (Mev for short), the energy acquired by an electron when accelerated by a stress of a million volts. When electrons strike an object their energy is transformed into x-rays emitted from the object—even television tubes emit some x-rays. These are electromagnetic radiations of the same nature as light, though of much shorter wavelength. Gamma rays belong to the same group, and are of still shorter wavelength; it is impossible to use the terms 'x-rays' and 'gamma rays' with enough precision to say at what wavelength x-rays cease to be and gamma rays begin.

In the common and familiar x-ray tube electrons are emitted by a heated filament and accelerated by a voltage applied between this filament, the cathode, and the target, the anode. So far, hardly any tube has had more than about 300,000 volts, giving x-rays of energy 0·3 Mev. It is extremely difficult to build tubes of this sort for voltages of even a million, and quite impracticable for still higher voltages because of the immense problems of insulation. (Anyone who has seen the discharge of a million volts in a high-voltage laboratory will remember the spacing involved to insulate the supply.) Other devices for accelerating electrons to high energy have therefore been devised.

Two firms in Britain—who leads the world in this development—have been concerned in the construction of such machines, Mullard and Metropolitan-Vickers. One device is the travelling-wave linear accelerator (see DISCOVERY, October 1954) in which electrons are caught up in the electric field of centimetric radio-waves travelling in a wave-guide. This wave travels faster and faster and so the transported electrons get more and more energy until they are travelling almost with the speed of light. The x-ray 'head', in which the electrons strike a metal target, is at the end of the wave-guide. Five linear accelerators for clinical use and research and giving x-rays of 4-Mev energy have been ordered by the National Health Service, and of these, three have been installed in hospitals at Newcastle, Liverpool and Manchester, while one is in the process of installation at a hospital in Edinburgh. The fifth is on order for the Mount Vernon Hospital in London. Radiotherapists have already had experience in the clinical use of x-rays of this energy with human patients, and three precisely similar 4-Mev machines have been ordered for hospitals in Australia. An 8-Mev linear accelerator was installed in the Hammersmith Hospital in 1952 and has been used by staff of the Medical Research Council there since February 1953.

One of 15-Mev has just been installed at Bart's Hospital; this was bought by the hospital itself, and is not a M.R.C. project. Research with this instrument on the physics side is being organised by Prof. Rotblat, head of the physics department of Bart's Hospital.

A different device is the cobalt unit. This depends on a small quantity of radioactive cobalt 60, which emits gamma rays of high energy, of the order of rather less than 3 Mev. This isotope of cobalt has a half-life of just over five years. Cobalt 60 can be made only in reactors with high neutron flux-densities, so it was first prepared in the Chalk River pile in Canada. A radio-cobalt unit sent from Canada is already in use at the Mount Vernon Hospital. Britain is now making her own cobalt 60, and a radiotherapy unit using British radio-cobalt has been installed at a hospital in Bristol.

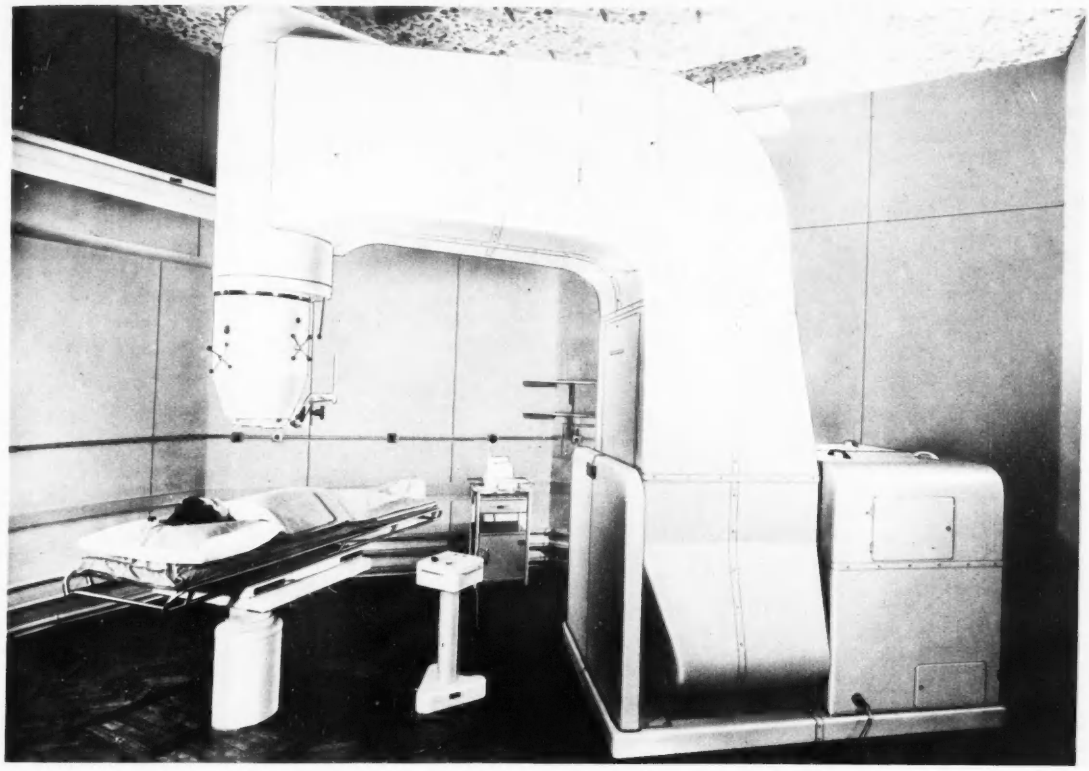
The most powerful machine of all has been installed at the Christie Hospital and Holt Radium Institute at Manchester. It is an M.R.C. project and was presented to the hospital by the makers, Metropolitan-Vickers. It is a betatron, and it gives x-rays of 20 Mev.

This is the first British clinical adaptation of the betatron, an instrument which was invented by Kerst in America in 1941 and is usually considered a tool of physics research. It is, as the name implies, an accelerator of β-particles or electrons. The machine consists essentially of an enormous electromagnet with a narrow gap over a considerable horizontal area. The magnetic lines of force, in other words, are vertical. In this gap rests a glass tube bent round into a ring. When the machine is operated this ring-shaped tube is continuously evacuated.

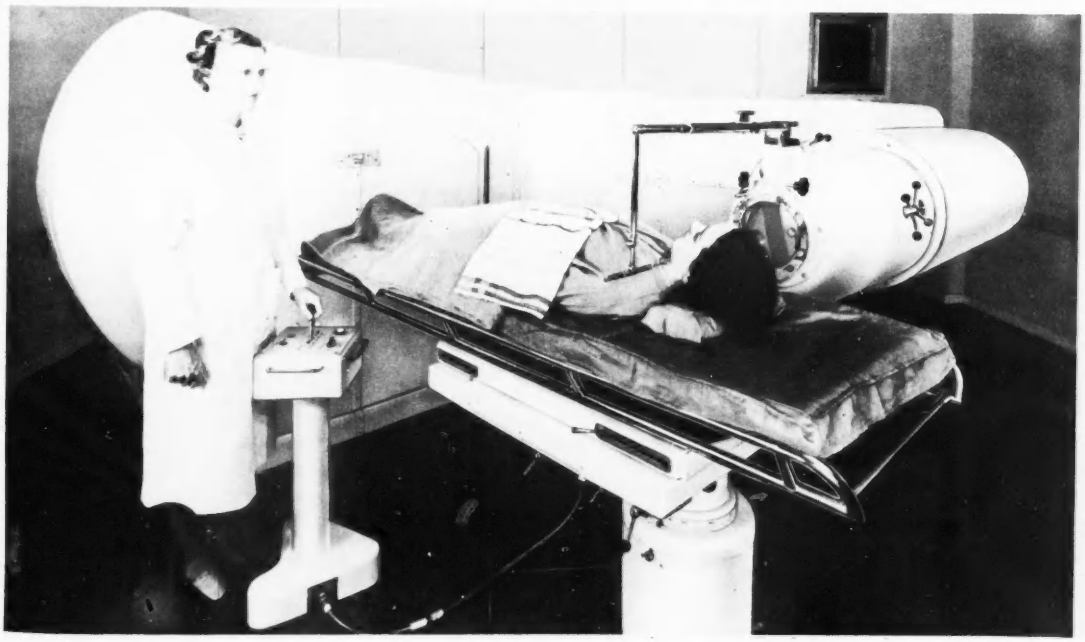
An electron-gun shoots electrons of 60,000 electron-volts into the tube and along its axis. At the same time the magnetic field is at a very small value. The interaction of magnetic field and electron motion constrains the electrons to a circular orbit. As they move round the tube the magnetic field is increasing, because the electrical supply to the magnet is alternating and the whole action of the betatron takes place in the first quarter-cycle. The changing magnetic field induces electric current. The moving electrons *are* the electric current and so, as a result of the increasing magnetic field, they gain energy.

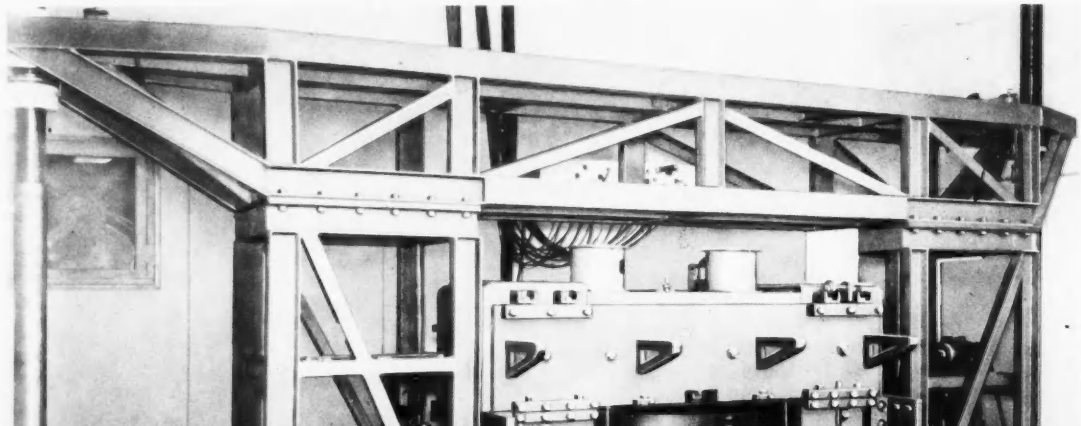
In the betatron shown they gain about 80 electron-volts per revolution. The frequency of the alternating supply is 150 cycles per second, so that the whole operation of acceleration is over in a quarter of this time, one six-hundredth of a second. In this time the electrons make about a quarter of a million revolutions. At the appropriate moment the circular orbit is expanded, and the beam of electrons is projected on to a tiny target and thus x-rays are produced. The time for which the electrons hit the target is two microseconds. The output of x-rays thus occurs in pulses lasting for this length of time and recurring 150 times every second. (This use of pulse emission is also characteristic of linear accelerators.)

The therapeutic use of all these machines presents



Two pictures of the Metropolitan-Vickers 4-Mev Orthotron at the Christie Hospital and Holt Radium Institute, Manchester. The x-ray beam is shown in a vertical position (*top*) and horizontal position (*bottom*).





The Metropolitan-Vickers 20-MeV betatron during installation at the Christie Hospital and Holt Radium Institute, Manchester.

special design problems. The designer must particularly allow for the fact that the sick patient must not be uncomfortable or subjected to much movement. Very short duration of treatment is already ensured by the high emission of the machines. There must be precise measurement of the dose of x-rays, and a construction that allows rotation of all or part of the machine; ideally provision is also made for movement, in both horizontal and vertical directions. The magnet alone of this medical betatron weighs seven and a half tons; it can be seen that the problem of easy and controllable movement is considerable.

x-rays, in their passage through matter, can behave in several different ways, some of which are known from the work of physicists. The process of absorption is complex, so that there is a point of maximum dosage not at the surface but at some distance inside. x-rays of 1-Mev energy, for example, give their maximum dose considerably less than a centimetre below the surface, whereas 4-Mev x-rays have their maximum effect at between one and two centimetres, and 20-Mev x-rays at a depth of three centimetres.

This is due partly to a directional effect, presumably of ejected electrons, such that the higher the energy of the x-ray beam, the more the ejected electrons are aligned in the forward direction. This means that there is less spread of damage to surrounding tissue. The resulting clinical picture is that the higher the energy of the x-rays, the deeper is the penetration, and the less the damage to intervening skin and healthy tissue. An additional advantage is that bone is as transparent as flesh to x-rays of high energy, so that bone cannot screen a tumour and prevent its treatment.

The directional effect means that if enough energy is left in the x-rays to leave the body at the opposite side, there is bound to be there an *increased* skin reaction. This sets a limit to the clinical usefulness of x-rays of energy greater than about 20 Mev, so that the Metrovick betatron represents practical finality in x-ray machines for radiotherapy. This machine, and the Mullard 15-Mev linear accelerator at Bart's Hospital will, because of the still unknown effects of such x-rays, be used for years purely for research purposes. They will be used to irradiate a range of experimental material; it is intended to investigate the effects of the rays on such things as tissue cultures and fertile eggs. Later the experiments will be extended to small laboratory animals.

The 4-Mev machines, on the other hand, will be in general use for therapy quite soon. With them it is expected—to quote the view of Dr. Ralston Paterson, director of the Radiotherapy Department at the Christie Hospital—that the cure-rate of cancers already known to be responsive to radiotherapy will be considerably increased.

RESEARCH IN MECHANICAL ENGINEERING

A. G. THOMSON

The development of mechanical engineering science is of fundamental importance to industrial progress in a great many fields. For this reason it is highly encouraging to record the way in which Britain's research effort dealing with the big problems of mechanical engineering is expanding. Much credit for that expansion should be given to the members of the committee, which was set up soon after the war under the chairmanship of Sir Henry Guy and which carefully considered the varied research needs of this branch of applied science. After a comprehensive review of the work being done by government establishments, by research associations, and by industry, the Guy committee recommended that a new research organisation should be established by the DSIR to undertake basic research, not systematically carried out elsewhere, over the whole field of mechanical engineering. This field was broken down into seven main divisions: namely, properties of materials; mechanics of solids; mechanics of fluids; lubrication; mechanisms and metrology; formation and shaping of materials; and heat transfer.

The committee's recommendations led directly to the setting up of a Mechanical Engineering Research Board in December 1946. In the following year the DSIR appointed the late Mr. G. A. Hankins, D.Sc., director of Mechanical Engineering Research. The core of the new research organisation under Mr. Hankins was formed by transferring to the Mechanical Engineering Research Laboratory (MERL) the bulk of the Engineering Division of the National Physical Laboratory; some of the work of NPL's Metrology Division was also transferred to MERL.

It was decided that the Mechanical Engineering Research Laboratory should be located in Scotland, and a site of about seventy acres was therefore acquired in the new town of East Kilbride, some ten miles south-east of Glasgow. The construction of buildings was started there in October 1949. In the same year the department took over an existing house and several large huts at Thorntonhall, on the western boundary of East Kilbride. The building programme was held up as a result of the restrictions imposed on DSIR expenditure in 1951, but the situation has much improved since December 1953 (when the DSIR was granted £6 million for new buildings for the period 1954–9) and this will enable much of the original building programme to be completed by 1959. The estimated cost of the Mechanical Engineering Research Laboratory is well over £2 million. The laboratory will then have a staff of between 600 and 700, and will be the second largest research station administered by the DSIR.

The first building to be completed at East Kilbride was the workshop, and this provides comprehensive facilities for making special research apparatus, as well as for the manufacture, repair and calibration of instruments.

The first stage of the Properties of Materials Laboratory has also been completed, but for the present this laboratory is being used as a general-purpose building which accommodates the whole or parts of five of the other six research divisions.

At Thorntonhall one large hut and parts of two others have been equipped as temporary laboratories for lubrication research. Other small laboratories have been equipped for research on machine shaping of materials, extrusion, forging and the performance of gears running under load.

Despite the pressure on available accommodation, considerable progress has been achieved in the establishment of this new research station. The staff employed at East Kilbride and Thorntonhall now totals over 300, of whom over 120 are scientific experimental officers, and all the divisions are now in active operation. The work of East Kilbride is supplemented by a number of sponsored investigations which the MERL has commissioned the universities to do.

For the time being the two divisions concerned respectively with properties of materials and mechanics of solids have been combined. The main objective of engineering research on the properties of materials is to enable engineers to use existing materials in the most efficient manner and to assist in the development of better materials. Thus the work ranges from fundamental research on the physics of solids to laboratory testing on particular engineering components. One of the most important problems in this field is presented by the phenomenon known as 'fatigue', which is still imperfectly understood. There are engineering components in everyday use which have to stand some hundreds of millions of applications of stress without breaking; as 90% of the failures are due to fatigue, MERL is obviously justified in putting a big effort into a systematic examination of the behaviour of materials under repeated stress. As part of its service to industry, the laboratory investigates the causes of unexpected failures of materials brought to its notice by industrial firms.

Another group of scientists at MERL is studying the effects of complex stress systems on materials at high temperatures. For increased efficiency in heat engines of all types there is a continuous demand for materials that will function satisfactorily at temperatures much above those at present in use. More detailed studies of the behaviour of engineering materials at high temperatures under fatigue and vibratory stresses are urgently required. One of the problems involved in the use of higher operating temperatures is the tendency of many metals and alloys to 'creep' or become deformed under steady load. To this phenomenon particular attention is being devoted.

MERL's equipment includes static testing machines covering all ranges of load up to 400,000 lb. tension and compression and 60,000 lb./in. torsion. The largest direct stress fatigue machine at East Kilbride can impose loads up to 2000 times a minute. Equipment has been designed and built which can determine torsional creep rates of 10^{-9} per hour. A high temperature creep and fatigue laboratory will be constructed as part of the 'five-year plan'. Meanwhile a small laboratory to study the effect of combined stress at high temperatures has been set up in the general purposes building.

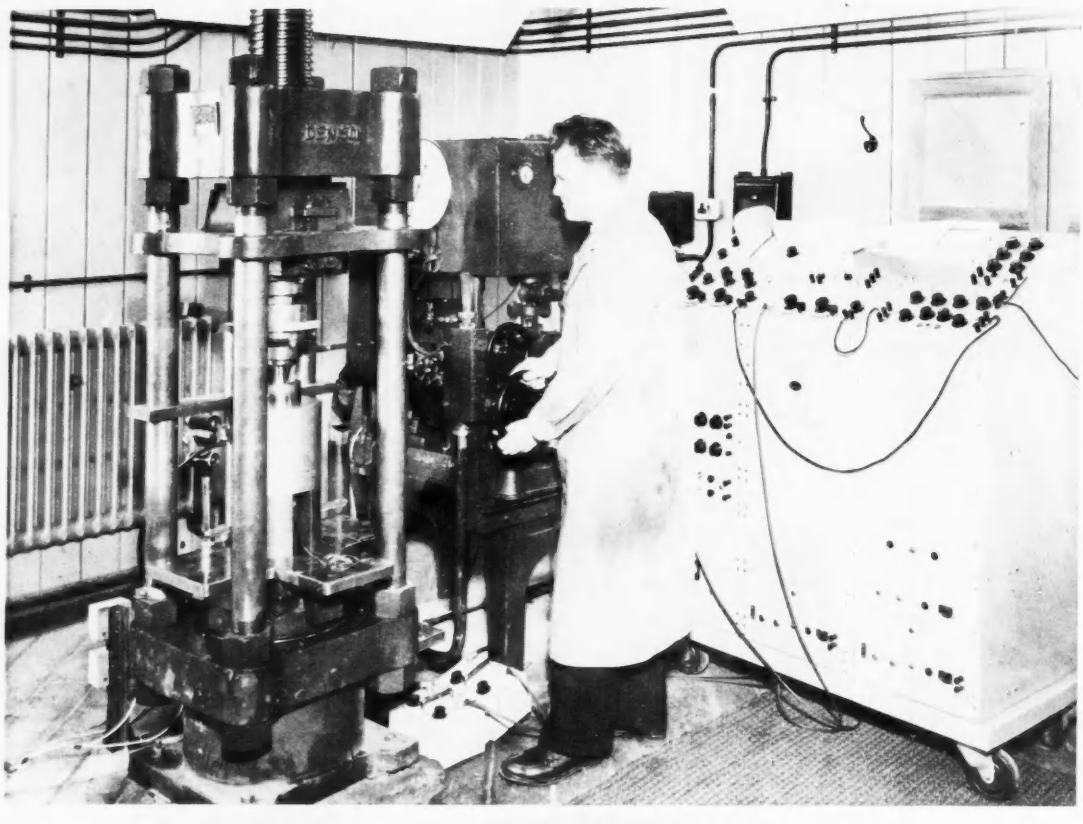


FIG. 1. (*above*). Extrusion research equipment at the Mechanical Engineering Research Laboratories.

FIG. 2 (*left*). A laboratory for work on heat transfer.

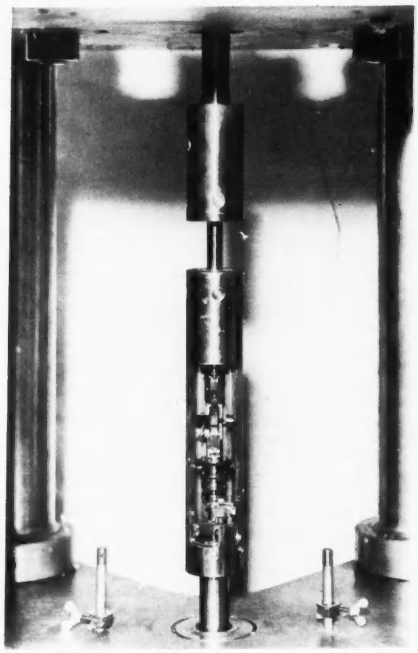


FIG. 3 (*left*). A combined extensometer and torsion meter for creep testing.

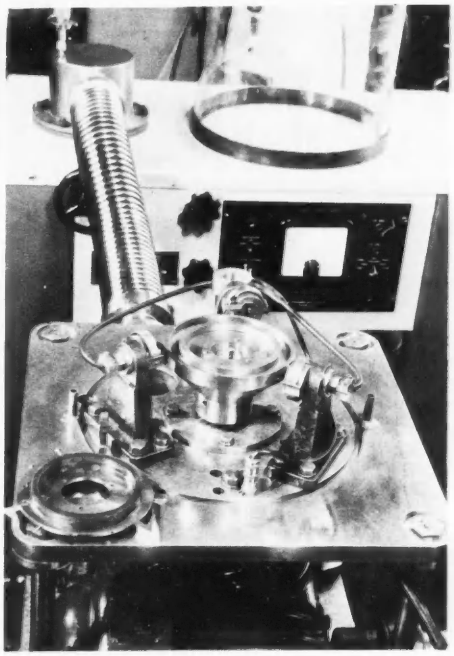


FIG. 4 (*right*). A controlled atmosphere wear machine.

A research programme covering the needs of all industries interested in the flow of fluids would be extremely wide. It was therefore decided to provide the Mechanics of Fluids Division with a laboratory designed primarily to serve the hydraulic machinery industry. With this objective before them, officers of the division visited other countries to obtain first-hand information regarding their research facilities, and the hydraulic machinery laboratory which incorporates many of the ideas which they picked up during their travels will be among the finest establishments of its kind in the world when it is completed. It will be provided with facilities for investigating problems connected with the design and operation of large water pumps and turbines. In addition this laboratory will investigate the flow of air and oil, and will therefore be in a position to shed new light on problems arising in the gas, oil and chemical industries.

The Plasticity Division is concerned with every aspect of plastic deformation involved in industrial processes such as rolling, wire drawing, turning and grinding. The research undertaken by this division ranges from fundamental studies of metal crystals to controlled experiments on a substantial scale of particular formation processes. If the forces, stresses and strains arising in any particular formation process can be calculated on the basis of an established theory, it should be practicable to design formation machinery on a much more exact and economical basis. Plastic deformation in extrusion and forging is at present being investigated at Thorntonhall.

Wherever there is machinery there are bearings to be lubricated and parts on which wear and corrosion must be minimised if the apparatus is to survive long enough to provide an adequate return to the user. Although lubrication has received much attention, the published work has been largely empirical in character and provides little guidance to designers faced with entirely new situations. In order to enable new extensions in fundamental knowledge to be rapidly translated into engineering terms, the research team which has been recruited to deal with the lubrication problems includes physicists, chemists and engineers. There will be three main lines of research: the first is concerned with the fundamental reactions which occur when two loaded surfaces slide over one another and into the mode of action of any lubricating material which may serve to separate them; the second line is basic research into the modes of lubrication and occurrence of wear in specific machine elements; finally the lubrication division will be dealing with the application of results to the solution of industrial problems.

Heat transfer is a big subject and one that is important in many branches of mechanical engineering, and also in chemical engineering and electrical engineering. Unfortunately the Heat Division has been gravely handicapped by lack of laboratory space, but a start has been made this year on the construction of this division's laboratory. At present much time is being spent on compiling of an up-to-date bibliography on heat transfer, and periodical reviews on particular aspects of this subject will be prepared. Some experimental studies have been started by this division.

The Mechanisms and Metrology Division has taken over some of the work previously undertaken at the NPL, and this will be expanded when the division's own specialised laboratory, which started building this year, is ready.

FAR AND NEAR

Night Sky in January

The Moon.—Full moon occurs on Jan. 8d 12h 44m U.T., and new moon on Jan. 24d 01h 06m. The following conjunctions with the moon take place:

January

9d 03h	Jupiter in conjunction with the moon		Jupiter	2° N.
18d 03h	Saturn	,,	Saturn	6° N.
20d 00h	Venus	,,	Venus	6° N.
25d 16h	Mercury	,,	Mercury	5° S.
29d 05h	Mars	,,	Mars	6° S.

In addition to these conjunctions with the moon, Jupiter is in conjunction with Pollux on Jan. 24d 21h, Jupiter 6°3′ S.

The Planets.—Mercury sets an hour after the sun on Jan. 15 and 1h 40m after sunset on Jan. 31; in the latter case it may be seen for a short time but as its declination is then about 12° S. it will not be an easy object to view. Venus, a morning star, rises about 4h 20m up to the middle of the month and at 4h 45m at the end of the month. The stellar magnitude varies between −4·3 and −4 and the visible portion of the illuminated disk between 0·348 and 0·528. The decrease in brightness, in spite of the increase in the visible portion of the illuminated disk, is due to the planet's recession from the earth —from 44·6 to 66·4 millions of miles— during January. Mars sets about 22h 25m throughout the month; its declination increases from about −5° to 4° 5′ and hence it is becoming better situated for observation. Its stellar magnitude varies from 0·9 to 1·2, the visible portion of its illuminated disk from 0·882 to 0·905, and its distance from the earth from 132 to 155 millions of miles. Its eastward movement from Aquarius into Pisces is easily seen but during the month it is not close to any bright star. Jupiter rises in the afternoon, at 17h 20m, 16h 15m and 14h 55m on Jan. 1, 15 and 31 respectively, and has a westward movement in Gemini. Its stellar magnitude remains −2·2 throughout January, its increase in distance from the earth being only a little over half a million miles, which does not affect the stellar magnitude to an appreciable extent. Saturn, a morning star, rises at 3h 45m, 2h 55m and 2h on Jan. 1, 15 and 31 respectively. Owing to its S. declination it does not attain a great altitude but can be seen in Libra, its slow eastward movement taking it towards γ Librae.

The earth reaches perihelion on Jan. 4, its distance from the sun being then a little less than 91¼ million miles. The Quadrantid meteors attain a maximum on Jan. 3, but moonlight will interfere with good observations of the shower. The radiant is at R.A. 15h 20m, Dec. 52 N., and the absence of conspicuous stars in this region renders the determination of the radiant somewhat difficult. Fortunately radar methods can supply fairly accurate data for the determination of radiants, irrespective of weather conditions or of the presence or otherwise of stars in the vicinity. It was first applied to the Quadrantid shower in 1948 and has been used since on many other showers with wonderful success.

Titanium Production in Britain by New Process

A recent conference was arranged by I.C.I. at one of their Birmingham factories to discuss the properties of titanium and its alloys, the problems of handling and joining the material, and questions of its availability. They witnessed the melting and preliminary fabrication in a pilot plant, saw the progress made in the construction of a large-scale melting plant, and were shown specimens illustrating titanium's outstanding properties of corrosion-resistance.

In the course of the conference it was confirmed that the process I.C.I. has developed uses sodium in the reduction of titanium tetrachloride. Their main plant, which is in an advanced stage of construction and will be in operation within a few months, will thus be the first large-scale production unit to operate a process other than that devised by Dr. Kroll, which came into prominence, particularly in the U.S.A., after the war. (In the Kroll process, magnesium is the reducing agent.)

This process in its essentials is not new. In fact, it was the method by which titanium was first isolated. It had been stated, however, that this reaction would be uncontrollable on a large scale, and the raw titanium sponge made by the sodium reduction of titanium tetrachloride would not have the necessary properties to allow good quality massive ingots to be made. The work in the I.C.I. Research Laboratories indicated that this was not necessarily true, and that, potentially, the reduction of titanium tetrachloride by sodium was economically attractive. The main research effort of the company was, therefore, turned to this process.

A semi-technical plant was erected in 1953, and a larger pilot plant was erected and started operation early in 1954. The results obtained on these plants have confirmed the early work, both in the quality of the product obtained and in the efficiency of the process, and have also solved many of the problems connected with the design of a large plant. Such was the faith of the company in the sodium process that it took the decision to build, and started design on, the large-scale plant late in 1953, well before the pilot plant started operation. This large-scale plant is being built in the north of England, and, construction having gone according to schedule, it is expected that the first units will come into production in the first half of 1955, and that full production will be reached before August.

Meanwhile, the pilot plant has worked steadily, and many tons of material have been produced and sold. The product from the plant is in the form of granules, which can be compressed into pellets for melting. After the melting into ingots, the material has a hardness which compares favourably with the product by the Kroll process, and meets the exacting demands of the users. The quality of the I.C.I. product is fully up to requirements in all respects, not only with regard to the specification for hardness—probably the most difficult property to control—but particularly with regard to its freedom from undesirable impurities.

The capacity of the full-scale plant will be 1500 tons of titanium sponge a year. Though this capacity may seem small compared with the announced intentions of the American makers, it is not much less than the amount of titanium sponge actually produced in America in 1953 (2250 short tons). The plant has been designed so that it can be expanded when required.

Archaeology in the Laboratory

The idea that tannins, by inhibiting the activities of the sulphate-reducing bacteria in soil, help to protect iron from corrosion underground has gained further support as a result of collaboration between experts in various scientific fields and the Ministry of Works on some of the recent finds from the Ministry's 'rescue' excavations at Chew Stoke, in Somerset. Since the cost of replacing corroded pipelines buried in the ground amounts to several millions of pounds a year, the significance of this inhibiting technique is plain enough, and the method is already being given extensive field trials.

It was first realised that some such agent was at work when archaeologists, excavating a site at Hungate, in York, two or three years ago, dug up a number of iron objects in an excellent state of preservation. The Ministry asked the Chemical Research Laboratory of the Department of Scientific and Industrial Research to look into the matter, and their Mr. T. W. Farrer found tannin-like substances in soil from the site. Using pure tannins, he proceeded to prove in the laboratory that they do, in fact, inhibit the activity of these bacteria. It seemed reasonable to assume, since one would, for instance, expect the leather articles from the site to contain tannins, that that is what happened in the ground. Yet Dr. Theodore White, of the Forestal Central Laboratories, was unable to detect tannins in the leather sent to him for analysis—perhaps because the samples were no longer fresh.

No time was lost, therefore, when further examples of iron objects in a remarkable state of preservation were recovered from the well of a Roman villa at Chew Stoke. And this time, Dr. White was able to show distinct amounts of tannin left in samples of wood that included hazel, elder, larch and oak.

Atomic Lighting Schemes

Preliminary planning and research is under way to supply New York City with electric power from atomic energy. The Consolidated Edison Company, the firm that supplies electricity to the New York area, has announced that it is carrying out, "with some urgency", a programme to utilise atomic energy plants to meet increasing demands for electricity. Planning and construction of an atomic-powered generating plant would take at least five years. Work is already under way on such a plant near Pittsburgh, Pennsylvania, owned by the U.S. Atomic Energy Commission.

The 1954 Atomic Energy Act—which provides that the U.S. may share atomic developments with other nations—includes a section that encourages private industry to use the atom for power.

Germany's Nuclear Fuel Production

The West German Chancellor, Dr. Adenauer, has given an assurance about the quantities of nuclear fuel the country will produce during the next two years. In a letter to Sir Anthony Eden, Dr. Adenauer states that the German atomic experts have come to the conclusion that it will be sufficient during the next two years to build one nuclear reactor with a capacity not exceeding 10 megawatts. The letter continues as follows:

> "The Federal Government intends to ensure that during this period nuclear reactor capacity will not be installed in the Federal Republic in excess of this figure, and also that the total supply of nuclear fuels for civil purposes, i.e. plutonium, uranium 233, and uranium 235, whether manufactured or imported, will not exceed 3500 grammes in any one year. It is my intention that the two Governments should continue to keep in touch in questions concerning atomic energy and consult together."

The full text of the letter is published as a White Paper (Cmd. 9323, Stationery Office, 3*d*.).

Arid Zone Research Reviewed

Unesco's Advisory Committee on Arid Zone Research held its eighth session at the National Physical Laboratory in New Delhi recently, and also spent a week on a study tour of the Rajasthan Desert.

During the session, the committee held a symposium on wind and solar energy with eleven scientific papers—four of them on the use of wind-power and seven on solar energy.

The only new research authorised by the committee is an ecological study of the camel in the north-west Sahara. This will be carried out by Dr. Hilda Pilters. She will investigate the camel pastures and choice of vegetation, and exhaustion of pastures and the requirements for their regeneration. The amount of food required by the camel and what plants it prefers when grazing freely are not known, nor is the value of the various types of pastures. This research will be an extension of the physiological study of the camel made in the Sahara by Dr. and Mrs. Knut Schmidt-Nielsen of Duke University at the desert oasis of Beni Abbes. The Duke study has now been completed but is not yet published. The data obtained are surprising. The camel can stand an increase in its body temperature of as much as 11°F above normal, a temperature which would indicate a critical fever in man and in most other animals. The camel, however, does not keep its temperature normal by perspiring. Even at a very high temperature it perspires only slightly. This is one of the reasons why the camel can exist for weeks and months without taking water. One camel was in good condition after seventeen days on nothing but hay and dried dates, although it was kept in the scorching sun at a temperature above 100°F. At the end of seventeen days, the camel stopped eating and lost one-third of its body weight. It was then allowed to drink and took in almost twenty gallons of water. Another camel drank thirty gallons in ten minutes. The old question as to where the camel stores so much water is still not answered, but Dr. Schmidt-Nielsen finds no special storage compartment. The hump consists of fat and takes no water. The stomach has no unusual provision for storage. The water taken in thus enters the other body fluids but it is not known how the camel can tolerate such a sudden dilution of its blood.

Colonial Research Grants now Total £13 million

Grants totalling £728,510 were approved for forty-two new Colonial research schemes and forty-nine supplementary schemes in 1953–54 states the latest report of the Colonial Research Council, published under the title of *Colonial Research, 1953–4* (H.M. Stationery Office, Cmd. No. 9303, 7*s*. 6*d*.).

Grants allotted to Colonial Development and Welfare Research schemes since 1940 amount to some £12 million. About one-third of the money has been for agricultural, animal health and forestry schemes, 15% for medical research, 12% for fisheries research, 10% for tsetse and trypanosomiasis research, 9% for social science and economic research, 8% for insecticides research, 5% for research sponsored by the Colonial Products Research Council, 3·3% for anti-locust research and 4·6% for miscellaneous schemes including building and road research.

New Head of Navy's Scientific Service

DR. H. F. WILLIS has been appointed chief of the Royal Naval Scientific Service in succession to W. R. J. COOK, who has joined the staff of the Atomic Energy Authority.

Born in Cardiff in 1909, Dr. Willis was until recently superintendent of the Admiralty Research Laboratory at Teddington. He entered the service of the Admiralty in 1938 and has been responsible, both as a group leader and as a theoretician, for much valuable and original scientific work.

Graduating from University College, Cardiff, he went on to Trinity College, Cambridge, and in 1935 joined the staff of the British Cotton Research Association, Manchester.

His first appointment after joining Admiralty service was concerned with anti-submarine research at Portland and afterwards at Fairlie, Scotland. He remained on these duties until his appointment in May 1945, to the Admiralty Research Laboratory, of which he became superintendent in February 1953.

* * *

DR. L. F. C. NORTHCOTT has been promoted to deputy chief scientific officer and appointed senior superintendent of applied research at the Armament Research Establishment, Fort Halstead. Dr. Northcott has been a superintendent in the metallurgical research department of A.R.E. since 1947.

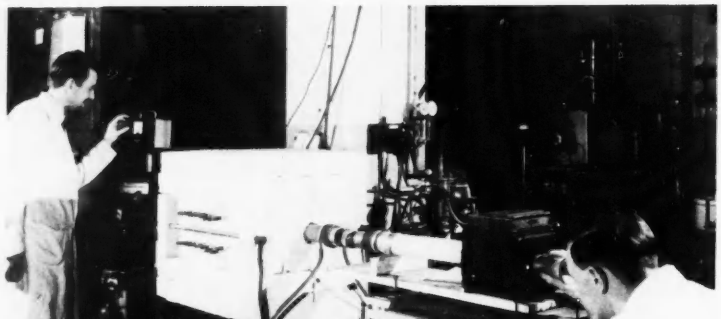
Graduates in Industry

The Federation of British Industries has just published two complementary handbooks on the subject of graduates in industry.

The first, *A Career for the Graduate in Industry*, is addressed to the undergraduate, and shows that there is a wide variety of satisfying careers in industry, both for the science and the arts graduate. It estimates that about 20% of the staff posts in industry could be suitably filled by graduates. The booklet then traces the likely career of both the science and arts graduate, discusses his prospects, and adds a note on salaries.

The second handbook, *Industry and the Graduate*, is addressed to industry itself. The booklet suggests how both science and arts graduates can be employed to the best advantage, how they can be recruited, and how they should be treated during the sometimes difficult initial years.

The price of each of these handbooks is 2*s*. post free from the Federation of British Industries, 21 Tothill Street, London, S.W.1.



Test furnace built from the bricks known as M 128 and having its high temperature provided by silicon carbide rods.

Metal-Ceramics and Gas-Turbine Developments

The trend of gas-turbine development is towards higher temperatures, and progress in that direction depends upon finding metals or other materials which retain their mechanical strength at high operating temperatures. One line of research which offers promise in this direction is concerned with what are called metal-ceramics. These are mixtures of metals and ceramics. They are prepared by mixing powdered metal and powdered ceramic; the resultant material can be pressed into components of the required shape, and this is done by the method of pressing already perfected in connexion with powder metallurgy, and certain other methods are also being tested. The components are then sintered, when they acquire solidity and great hardness. One of the key centres where investigations on metal-ceramics are being carried out is the Central Research Department of the Morgan Crucible Company in London. These laboratories have already produced experimental gas-turbine blades in this new type of engineering material.

Probably the first commercial application of metal-ceramics which will emerge will be thermocouple caps. Tests show that these should have a much longer life than caps made of fused silica, and it is expected that they should be on the market in a matter of eighteen months or so.

The metal-ceramics are the concern of the special section of these laboratories devoted to the study of high-temperature chemistry, a field of particular importance to this company with its interest in the production of refractories designed to stand industrial use at very high temperatures. Apparatus has been developed in this particular laboratory in order to get data about reactions occurring in the temperature range of 1500–2500°C. There is, for instance, an experimental furnace which can be built from a particular kind of refractory brick (known as M128) in as little as a day. The high temperature is provided by silicon carbide rods.

One of the firm's specialities is carbon brushes for electrical machines, and it is interesting to learn that *radioactive isotope techniques are being used to study possible formation of films by carbon brushes running on copper commutators and investigations are proceeding into the formation of refractory coatings for carbon and graphite.* In these experiments the carbon brushes contain a radioactive isotope, and this makes it comparatively easy to measure the rate at which the brushes are worn away.

'Megistor', which has very high electrical resistance (up to 10^{13} ohms), was developed as a result of work done in Morgan's Central Research Department. This is being used in such things as radiation monitors.

French Ministry gives Priority to Nuclear Physics

The unprecedented creation of a post of Secretary of State for Scientific Research and Technical Progress, with M. Henri Longchambon in charge, on the accession of M. Mendès-France to the position of Prime Minister of France, has now been followed by a reorganisation of the governmental research institutes and the formulation of a plan for the future development of French science. M. Longchambon announced upon his appointment that there was no intention of creating a supplementary bureaucracy in his ministry, but that he meant to co-ordinate the programmes and budgets of the various research institutes that are now scattered in other ministries. He announced details of his programme in an interview with *Le Monde* (published on November 19).

M. Longchambon said that recently he had met with representatives of half a dozen government ministries which now control the various research institutes. These will continue in their present administrative framework but will be under the control of the Ministry of Scientific Research. They include the National Office of Aeronautical Studies and Research; the National Centre of Scientific Research; the Scientific and Technical Institute for Marine Fisheries; the Bureau of Geological and Geophysical Research; the National Institute of Agronomic Research; the Office of Overseas Scientific Research; the Scientific and Technical Centre for the Building Industry; the National Institute of Hygiene and the National Institute of Demographic Studies.

Specific new measures announced by M. Longchambon include the following: substitution for the existing chair of nuclear physics at the Sorbonne of an institute equipped with a synchro-cyclotron of 100 million volts, a particle accelerator of 2 million volts and an isotopic separator; development of the centre for nuclear physics at Strasbourg, where the personnel will be increased and a new building with an accelerator of 6 million volts will be constructed; extension of the institute for atomic physics at Lyons, which will also be equipped with a more powerful accelerator; the creation at Grenoble of a centre of nuclear physics to be equipped with an accelerator of a wholly French design.

Furthermore, the Atomic Energy Commission will undertake the construction of an accelerator of 2000 million electron-volts and will inaugurate courses of practical instruction at Saclay. The laboratory of atomic synthesis at Ivry will be equipped with a betatron, the one at the Ecole Normale Supérieure with an accelerator of 2 million volts, while at Orsay a laboratory will be opened fitted with a synchro-cyclotron of 500 million volts, of French construction. M. Longchambon foresees the eventual development and installation of a motor utilising atomic energy.

These projects, which are already in the budget for 1955, obviously give priority to nuclear physics. Nevertheless, the other branches of research are not to be neglected. The intention is to create or develop the following institutes, for inorganic chemistry at Lyons, for structural organic chemistry at Montpellier, for chemical kinetics and physical chemistry at Nancy, for plant physiology at Gif-sur-Yvette, a centre

for biological chemistry at Marseilles and a centre for electrostatics and the physics of metals at Grenoble. The whole forms a coherent plan in the realisation of which a number of ministries and departments must co-operate and which, according to M. Longchambon, could be achieved only under the responsibility of a single authority within the government.

New Dean of Royal Military College of Science

The War Office has announced the appointment of Prof. S. J. Davies as Dean of the Royal Military College of Science, Shrivenham. To take up this post, Prof. Davies gives up the Chair of mechanical engineering at King's College, London University.

New Laboratories for Rubber Research

The Duke of Edinburgh officially opened the new laboratories of the Research Association of British Rubber Manufacturers at Shawbury, near Shrewsbury. This research association was founded in 1919. It now has about 300 firms supporting it, and the staff numbers over ninety.

Fishes that Live on Fish Scales

In a letter to *Nature* (1954, vol. 174, p. 935) two scientists of the Institut pour la Recherche Scientifique en Afrique Centrale, at Uvira in the Belgian Congo, report on a species of fish the diet of which is fish scales from other fishes. In 1949 it had been discovered by another scientist that in species of the genus *Plecodus* the stomach often contained practically nothing but fish scales. Now it has been established that individuals of one of these species cannot be fed on anything except the scales of live fish. The two scientists state that when a *Plecodus* attacks another fish successfully, it pushes its mouth against the back of its victim for a short while, and when it swims off afterwards there is left behind a spot which is denuded of scales.

New Editor of "Endeavour"

Dr. Trevor Williams, who has been deputy editor of *Endeavour* since 1945, has succeeded Dr. E. J. Holmyard as editor. Dr. Williams is well known to our readers through the articles he has contributed to DISCOVERY, and he has written several books on chromatography.

Dr. Holmyard used to be head of the Science Department at Clifton College before joining *Endeavour*. His textbooks on chemistry have been widely used in schools. Although he has retired from the editorial chair of *Endeavour* Dr. Holmyard is not wholly severing his association with I.C.I., for he is continuing, with Dr. Charles Singer, his work as an editor of the Company's comprehensive *History of Technology*, the first volume of which is to be published shortly.

The Drummond Fellowship

Applications are invited for the Drummond fellowship for research in nutrition, which will be awarded about March next year. The fellowship is worth £900 a year, normally tenable for two years, with up to £50 a year research expenses and £90 superannuation. Application forms, to be returned by January 15, and further information can be obtained from the Honorary Secretary, Drummond Trust, University College, Gower Street, London, W.C.1.

The New Royal Medallists

Two Royal Medals are presented by the Royal Society each year, and the latest recipients of this high honour are SIR JOHN COCKCROFT, director of the Atomic Energy Research Establishment, Harwell, and PROF. H. A. KREBS, Whitley professor of biochemistry in the University of Oxford.

New Insecticidal Lacquer

The British troopship *Dunera* recently left Southampton docks for the Far East after it had been treated against insects by means of a new insecticidal lacquer. The lacquer, which was developed after three years of continuous research, contains the Shell insecticides, aldrin and dieldrin, and is covered by a British patent filed by the National Research Development Corporation, reports *The Chemical Age* (Aug. 21, 1954).

The newly discovered lacquer is said to have the unique property of expelling the insecticides in minute crystals, an action quickened by the friction of insects crawling on the surface. Lethal properties persist for at least two years after application despite repeated washing and scrubbing.

Aldrin and dieldrin were developed comparatively recently by Shell, who are building a new £1 million plant for their manufacture at Pernis near Rotterdam. They have been found dramatically successful in controlling a very wide range of insects in all parts of the world, notably locusts, seaweed fly and many agricultural pests.

The formulation of the lacquer is as follows:

	parts by wt.
Urea Resin (Type B.C.555)	50
Alkyd Resin (Type B.C.666)	50
Butanol	27·5
Xylole	22·5
Dieldrin	12
Aldrin	12

The accelerator (sulphuric acid 10% volume) is finally added to the above in the proportion of 1 : 20.

Announcements

This year the annual exhibition of the Physical Society will be held during the period April 25–28. Detailed information about it can be obtained from the Hon. Exhibition Secretary, Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

* * *

The next National Radio Show is to be held at Earl's Court, London, from August 24 to September 3.

A smaller in the north is planned, to be held at the City Hall, Manchester. Both exhibitions are organised by the Radio Industry Council, 59 Russell Square, London, W.C.1.

LETTER TO THE EDITOR

THE PERIODIC TABLE

Sir:

In his article "A New Approach to the Periodic Table" (DISCOVERY, vol. 15, p. 375) Dr. Tomkeieff has emphasised that the application of x-rays to the study of matter combined with the quantum theory of radiation endowed the Periodic Table with a new and much more profound significance, and has erroneously averred that at that time it was a mere scheme of classification.

Many other writers in recent years have made similar claims for developments that occurred in other branches of physics, and all of them have this in common with Dr. Tomkeieff that they have completely ignored the earlier contributions made by chemists in the study of radioelements.

The concepts of isotopes and of atomic numbers were the outcome of chemical investigations followed by the placing of radioelements in the Periodic Table. Notable contributions to this work, made by Fleck and Soddy, may be seen in the reports of the British Association meetings of 1911 and 1913, and in various papers published in the *Chemical News* and the *Transactions of the Chemical Society* in 1912 and 1913. This work was acknowledged by Bohr in his original papers and preceded the brilliant extension by Moseley of the concept of atomic numbers to the stable elements (published in the *Philosophical Magazine* in 1913 and 1914).

JOHN A. CRANSTON.
The Royal Technical College, George Street, Glasgow, C.1.

Dr. Tomkeieff makes the following comment on Dr. Cranston's letter:

In this very brief reply to Dr. Cranston may I say, that the periodic classification of elements, in its modern form, is based entirely on the concept of atomic species. Nuclear species and, in particular isotopes as such, do not enter into this classification. This, however, does not mean that they are neglected. They can be included in a periodic table in which weight is one of the dimensions. In my short article published in DISCOVERY exigency of space precluded my discussing the periodic system in its historical aspect; I could only indicate a new approach to it.

THE BOOKSHELF

The Distribution of the Human Blood Groups

By A. E. Mourant (*Oxford, Blackwell Scientific Publications, 1954, 438 pp., 42s.*)

The fact that one kind of human blood curdles another when they are mixed and that human beings can be grouped by their blood according to their properties in this respect was discovered over fifty years ago. Later it was discovered that the groups are genetically determined and subject to an utterly precise Mendelian inheritance which has thrown new light on the interpretation of the gene itself. Much more recently it was found that a dozen independent systems of blood groups and blood characters exist in mankind. Many more systems certainly will be found. Most races vary in respect of most blood groups. The frequencies of types allow us to map the human species for the distribution of the genes concerned. And where the differences are not local but social the consequences are even more instructive.

Mourant's new book describes the techniques we now use and summarises the evidence we now have. A bibliography of 1700 papers indicates the activity that is going on.

The first great problem that meets us will be the last problem to be solved. It is the problem of how far the distribution of blood group genes reflects the ancestry and relationships of human populations. Clearly it will always reflect immediate relationships. But how long does the evidence persist? How quickly does natural selection modify the proportions of blood-group genes in populations which are kept free from serious contamination? The answer we may expect is that it will depend on three internal variables, on the particular gene, on its neighbours in the chromosome (which are both movable and variable) and on the genotypes which make up the racial character of the whole population. A fourth variable, the environment, the external conditions in which the population lives, must also have an effect. But it acts chiefly through the different kinds of diseases to which different populations are liable, and to which different individuals within each population are susceptible.

The most striking evidence of these kinds of selection has been revealed in work described by Dr. Mourant. It is now known that individuals with blood group 'A' are more susceptible to cancer of the stomach and individuals of blood group 'O' are more susceptible to ulcers of the stomach. The latter difference is of the order of 35%. This introduces selection against blood group 'A' or 'O' in races which on account of their general genetic character or their habits are susceptible to these diseases. Other genes which float in human populations affect the reactions of the blood itself to infectious diseases. For example, the gene which in pure state causes sickle-cell anaemia in the heterozygous state confers resistance to subtertian malaria. This gene has in consequence been favoured and has spread in populations subject to subtertian malaria, especially in Africa. The Rhesus gene is another instance of selection undoubtedly affecting the equilibrium frequency of the alternative conditions of the gene.

Millions of people have been recorded for their blood-group properties and the total result is to provide the largest body of information about population genetics that is available in any organism. Man, from being the poorest of all organisms for genetic study has in the last dozen years become the most opulent and generous. So obvious has this become that those who teach medical students are beginning to realise the need to know some of these basic facts of life. Dr. Mourant does not concern himself with such practical matters. His presentation also is marred inevitably by the fantastic and often contradictory terminology which has been largely inherited from pre-genetic or paleo-genetic times and which is now, we believe, about to be reformed. We must be grateful to him, however, for turning aside from his labours to give the world this progress report.

C. D. DARLINGTON

The Elements of Chromatography

By T. I. Williams (*London and Glasgow, Blackie & Son, 1954, 90 pp., 9s. 6d.*)

The rapid developments in the techniques of chromatography in the last decade have resulted in the publication of many varied papers on the subject. Dr. Williams, whose contributions are well known to readers of this journal, has carried out an extensive survey of the literature and presents the results in a new book, which is the successor to his original *An Introduction to Chromatography*.

The approach to the subject is descriptive rather than theoretical, the mathematical treatment being beyond the scope of the book. The main methods of separation depend upon adsorption, partition and ion exchange and these are discussed in detail with much practical information for carrying out successful analyses. Numerous examples and some excellent colour photographs illustrate the wide applications, ranging from simple inorganic analysis in adsorption columns to the separation of complex organic acids by two-dimensional analysis on filter paper.

The definition of chromatography includes other processes for resolving mixtures into their respective components such as electrophoresis and vapour phase separations, the importance of which is emphasised by the recent work on the separation of petroleum hydrocarbons. Although they are dealt with briefly in this book, the bibliography contains useful references which can be consulted.

The important aspect of development after separation, especially in the case of colourless substances, is dealt with in some detail and it is interesting to see that radioactive isotopes can play an important part in chromatography. Dr. Williams concludes with some speculations about industrial scale separations but it remains to be seen whether such methods are economically feasible.

There is no doubt that students new to the subject and the research worker who contemplates the use of chromatography will find this book a very useful basis for study, with an adequate bibliography for pursuing the subject in detail.

K. A. R. JULIAN

Medical and Scientific Investigations in the Christie Case

By Francis E. Camps (*London, Hutchinson's Medical Publications, 1953, 244 pp., 30s.*)

While every famous trial in Britain has been set on record in book form for the enlightenment of future generations, the Christie case has given rise to something quite different—a detailed account of the medical and scientific investigations which preceded the trial of Christie. As it turned out, much of the evidence thus obtained was not used in the proceedings at the Old Bailey, as Christie was only tried—and convicted—for the murder of his wife. Nevertheless the evidence and the methods by which it was obtained is of very great interest to the police as well as to the forensic scientist, because many of the problems raised had to be tackled without the guidance of any precedent. They were satisfactorily solved and they now themselves constitute a precedent.

The case produced a unique series of examples of the changes which may occur after death, and which ranged from early mould formation in a cupboard to bare skeletal remains in a back garden. These examples showed how difficult it may be, on scientific evidence alone, to estimate the elapsed time since death in buried bodies whose soft tissues had disappeared. One of the most remarkable feats was the assembly of the skeletons from the bones found in the garden at Rillington Place.

The book is very well produced and contains forty-seven diagrams and photographs as well as six coloured plates, ranging from police photographs

to complicated radiographs of teeth and pictures of the stages in the reconstruction of the skeletons.

Animal Cytology and Evolution

By M. J. D. White (*London, Cambridge University Press, 2nd edn. 1954, 454 pp., 45s.*)

The first edition of *Animal Cytology and Evolution* was published in 1945: written during wartime, when the author had only limited access to libraries, it was nevertheless a remarkably comprehensive work. The second edition upholds the high standards of the first yet it, too, was written under some difficulty, the revision being started while the author was working in the United States and completed in Australia. Bearing also in mind how scattered and how variable in quality is original literature on chromosome cytology, the present polished work stands as a tribute to the author's perspicacity and tenacity of purpose, for he has contrived to write a readable, wide-ranging, withal critical book.

It is a great pleasure to read a cytology text where factual information and the author's speculations are clearly distinguishable from one another. All too frequently in recent years have works on this subject marshalled the facts so that they fit particular theoretical straitjackets and in such a way as to obscure the very many fundamental problems remaining to be solved within this field. White has certainly not been guilty of this crime. The present reviewer has read with particular pleasure White's rejection of facile distinctions made as between 'heterochromatin' and 'euchromatin': perhaps in a few years' time we will see this unfortunate terminology abandoned.

The book is profusely illustrated with drawings and diagrams, pleasing alike for their simplicity and clarity, and it ends with a most imposing list of some 1500 references. Being a study, as the author himself points out, of the "evolution of the evolutionary mechanism itself", White's book should be read by all serious students of biology as a companion work to Dobzhansky's *Genetics and the Origin of Species* and Huxley's *Evolution, the Modern Synthesis*. It should also be accessible to science undergraduates in general, for the information and ideas which it contains can be readily assimilated by anyone who has had some slight prior acquaintance with nuclear cytology. The present reviewer hopes that White's book will stimulate a recrudescence of interest in nuclear cytology, not only from a comparative evolutionary standpoint, but also with a view to discovering fundamental generalisations concerning the structure of genetic mechanisms which appear to be 'just around the corner'.

H. G. CALLAN

A Concise History of Mathematics

By Dirk J. Struik (*London, G. Bell, 1954, 299 pp., 14s.*)

This is an excellent book for the mathematical student, but it should also have a wide appeal to the scientist. To trace the history of mathematics from its earliest beginnings up to the end of the 19th century is no mean task, but to actually perform the apparent impossibility in under 300 pages is a major achievement, for which our thanks are due to Prof. Struik of the Mathematics Department of the Massachusetts Institute of Technology. In his introduction the author acknowledges the fact that in order to confine himself within the limit of this concise book he has made a strict selection of his material. He has developed a few main ideas and confined himself within rigid limits to other developments, especially the environmental factors, both cultural and sociological, which have influenced the development of mathematics throughout the ages. It is, nevertheless, an excellent treatment of an enthralling subject, and a book which deserves to be widely read.

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